‘Cleaner innovation’? A political process approach to environmental aspects of process technology innovations

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Abstract

This thesis seeks to improve our understanding of the integration of explicit environmental motives into innovation processes. This will be done by applying insights from the social shaping of technology field as well as organisation studies to the area of environmental innovation, which is dominated by environmental management literature.

The environmental innovation literature typically conflates the motives behind environmental innovations and the resulting technological outcomes, thus reifying environmental motives and causing confusion regarding the concepts of ‘environmental innovation’ and ‘cleaner technology’. We will here disentangle motives and outcomes and contextualise innovations in terms of other motives as well as other practices than those labelled environmental. An underlying assumption in the literature is also that firms are monolithic, rational actors where management decisions are implemented by straightforward translations into technological solutions, neglecting any influence from other actors in the firm. We will here instead investigate the processual and political aspects of innovations and their environmental aspects. Special attention will be given to the roles and expertise of engineers, environmental staff and managers. Moreover, a lot of the environmental innovation literature is determinist in its attempts to promote ‘best practice’ and the greening of firms. To avoid this we will, through a focus on the processual and structural dimensions of firm organisation, seek to distinguish between one-off contingencies and longer lasting changes. We will also be sensitive to the possibility that organisational change may lead to worse as well as better environmental performance.

This thesis looks at chemicals industry firms since they have a long history of exposure to environmental regulation, and are likely to have well-developed routines and expertise for environmental innovations. As a comparison dairy industry firms are also studied. To avoid decontextualisation and environmental management determinism, we chose cases irrespective of whether the environmental motive was central to the innovation or not. The cases include both core technology and end-of-pipe innovations. The data was collected mainly through semi-structured interviews with actors in the firms. The analysis is based on comparison of cases in the two industrial sectors, and in Sweden and Scotland.

A central result of the thesis is that we can and should distinguish between ‘unintentional’, ‘intentional’ and ‘ambitious’ cleaner technology innovations, depending on the role of environmental motives in the innovation process. We also saw that the environmental label could be doing purely rhetorical work independently of the design choices made. In fact, we saw no example of ambitious cleaner technology, and few cases of intentional cleaner technology, which is surprising given the choice of chemicals industry cases.

In terms of firm organisation, we have developed the concept of the Company Social Constitution to capture the structured context of environmental work in innovation processes. This helped us explain the roles of environmental staff as buffers and boundary spanners, in competition with engineers regarding technological work, and depending on current and past regulatory pressure. Finally, we were able to put forth a new theorisation of environmental championing that captures both structural and action aspects of organisational life to explain this behaviour.

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Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(Nils Markusson)

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List of abbreviations

A-CI	Ambitious cleaner innovation
AGA	Previously a Swedish industrial gas company
BATNEEC	Best available technology not entailing excessive costs
BAU	Business as usual
BAU-CI	Business as usual cleaner innovation
BBC	British Broadcasting Corporation
BOD	Biological oxygen demand
BP	British Petroleum
CFC	Chlorofluorocarbons
CI	Cleaner innovation
CIA	Chemical Industries Association
CIP	Cleaning in place
CIWEM	Chartered Institution of Water and Environmental Management
CIWM	Chartered Institution of Wastes Management
COD	Chemical oxygen demand
COWI	COWI Consulting Engineers and Planners AS
CSC	Company social constitution
CT	Cleaner technology
DEFRA	Department for Environment, Food and Rural Affairs
DfE	Design for Environment
DSCF	Dairy Supply Chain Forum
DTI	Department of Trade and Industry
E	Environment
EA	Environmental Protection Agency (England and Wales)
econ.	Economy
ECUK	Engineering Council UK
eff.	Efficiency
EHS	Environment, health and safety (see also HSE, SHE)
EI	Environmental impact
EIA	Environmental Impact Assessment
EMAS	Eco-Management and Audit Scheme

EMU 2000	Project at the Emulgol plant of Chemicals Sweden
ENDS	Environmental Data Services
ETP	Effluent treatment plant
EU	European Union
FDS	Functional design specification
GDP	Gross domestic product
GM	Genetically modified
GROS	General Register Office for Scotland
GVA	Gross value added
H&S	Health and safety
HQ	Headquarters
HSE	Health, safety and environment (see also SHE, EHS)
HSV	Högskoleverket (Swedish National Agency for Higher Education Agency)
IChemE	Institute of Chemical Engineers
ICI	Imperial Chemical Industries
I-CI	Intentional cleaner innovation
IEEM	Institute of Ecology and Environmental Management
IEMA	Institute of Environmental Management and Assessment
IPC	Integrated pollution control
IPPC	Integrated pollution prevention and control
ISCED	International standard classification of education
ISO	International Standards Organization
IT	Information technology
IVA	Ingenjörsvetenskapsakademin (Royal Swedish Academy of Engineering Sciences)
KPMG	A consultancy firm
LCA	Life cycle analysis
M	Managerial
MDC	Milk Development Council
MMB	Milk Marketing Boards
MMC	Monopolies and Mergers Commission
NGO	Non-governmental organisation
NMC	Näringslivets Miljöchefer (Swedish Association of Environmental Managers)

NV	Naturvårdsverket (Swedish Environmental Protection Agency)
O-CI	Cleaner innovation as defined by outcome
OECD	Organisation for Economic Co-operation and Development
P	Production
P&ID	Piping and instrumentation diagram
pH	Measure of acidity
PhD	Doctor of Philosophy
PK	Plast- och Kemiföretagen (Swedish Plastics and Chemicals Federation)
PQC	Process and Quality Control
PR	Proportional representation
prod.	Production
PSI	Policy Studies Institute
PT	Process Technology (a department at Chemicals Scotland)
PTD-SHE studies	Process Technology Department Safety, Health and Environment studies (a methodology used at Chemicals Scotland)
Q	Quality
R&D	Research and development
RE	Resource efficiency
REACH	Registration, Evaluation and Authorisation of Chemicals
reg.	Regulation
RSPB	Royal Society for the Protection of Birds
SCB	Statistiska Centralbyrån (Statistics Sweden)
SDA	Swedish Dairy Association
SEE	Society for Environmental Engineers
SEK	Swedish Krona
SEPA	Scottish Environmental Protection Agency
SHE	Safety, health and environment (see also HSE, EHS)
SNF	Svenska Naturskyddsföreningen (Swedish Society for Nature Conservation)
SO2	Sulphur dioxide
Soc Env	Society for the Environment
SPC	Sustainable production and consumption
SSM	Stockholm Stads Miljöförvaltning (Environment and Health Administration of the City of Stockholm)
STS	Science and technology studies

SUS	Service Unit Sweden (an organisational unit at Chemicals Sweden)
T	Technology (or engineering)
U-CI	Unintentional cleaner innovation
UK	United Kingdom
US	United States
UV	Ultraviolet
VINNOVA	Verket för Innovationssystem (Swedish Governmental Agency for Innovation Systems)
VOC	Volatile organic compounds
win-win-CI	Win-win cleaner innovation
WVS	World Values Survey

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1 Introduction

Over the last four decades environmental issues have received increased attention. In spite of efforts to manage pollution from production processes, manufacturing industry remains an important part of the problem, as well as a focus of environmental policy.

Recent years have seen widespread acceptance in policy – as well as academia – of the concept of ‘cleaner technology’, with particular emphasis on the so-called ‘win-win’ benefits that can stem from improvements in resource efficiency. With the cleaner technology concept now generally adopted by policy-makers and regulators it is important to understand what it entails in practice, and to address critically previous work on the topic.

1.1 Background

The wider concept of ‘environmental innovation’ has been used frequently to discuss environmental improvement through firm-level innovation. Broadly speaking, ‘environmental innovation’ is innovation that reduces the environmental impact of a manufacturing process (or of a product). Environmental innovations are often thought to entail either ‘end-of-pipe technology’, that is technology that collects and treats pollution, or ‘cleaner technology’, that is technology that reduces the production of pollution.

We set out these definitions only provisionally. Indeed, a central concern in this thesis is to scrutinise these concepts and to show why they are problematic. This is especially important given their use in environmental and – to a lesser extent – innovation policy.

We shall here set out the background of the thesis via an introduction to the notion of ‘environmental innovation’. First we shall make the case for the importance of this phenomenon. Thereafter we shall set out the history of the concept as well as its current use in government policy. And finally, we shall briefly discuss theories of the greening of society as a further context to the study.

1.1.1 Why environmental innovations?

Environmental problems have caused concern for a long time now, with early examples including polluted air in urban areas in the early 1900s (Stradling and Tarr 1999). Especially over the last 40 years such concerns have intensified with debates about issues such as the effect of pesticides on humans and animals, acidification of inland waters and, more recently, global warming and ozone holes. Concerns about environmental problems have been expressed in several ways, including a raised level of public concern, the growth of organized environmental movements and, not least, through government regulation of industrial activities.

The root cause of environmental problems has been traced back by different observers to different social structures and institutions, for example capitalism (Benton 1989), patriarchy (Shiva 1988) and Christianity (White 1967). A common trait among these explanations is a focus on the role of technology and how the ever-increasing use of technology means growing deleterious impacts of human activities on the natural environment. Early environmental advocates often expressed strong concern and pessimism regarding the possibility of ameliorating the negative effects of technology, at least without changing society radically – given the central role of technology in its workings (Hajer 1996:248).

In contemporary society firms have a central role in the development, distribution and use of resources and technology, and no small part of environmental pollution is produced directly by firms. Consequently, a lot of attention has been paid to the use of technology in industry. Society's response to environmental degradation has for a long time had a focus on regulating industrial pollution, and hence (more or less explicitly) regulating technology use in firms.

The environmental performance of business and the need for change have of course been debated, and it is possible to point to mechanisms that lead to both environmental degradation and to environmental improvements. On the one hand there is what economists would call externalisation, that is the possibility for firms to let others take responsibility (pay) for the environmental harm they have caused. It is quite simply often easier, cheaper and more profitable for the firm not to try to reduce the environmental impact of its activities. On the other hand, it is also in the interests of a firm to strive towards resource efficiency and to minimise waste. This may, however, require costly investments. All in all it seems that 'business as usual', that is not taking the environment into account, is not enough to reduce the environmental impact to tolerable levels, and that there is need for efforts targeted at improving the environmental performance of firms, be it by government regulation or by other means such as pressure from environmental activists.

Today, a common way of talking about firms' efforts to adapt their technologies to reduce their environmental impact is to talk of 'environmental innovation'. As we shall see in the next section, the view of the role of technology in relation to firms' environmental impacts has changed over time.

1.1.2 The history of 'environmental innovation'

There have been changes to the scope of environmental regulation over the past 40 years, and this has also meant changes in the kinds of environmental innovation that have been targeted, and how the concept of 'environmental innovation' has been understood. When modern environmental regulation began to develop in the 1960s it built upon existing approaches. The focus was on reducing the environmental impact of waste and pollution produced by industrial processes, and the technological means were so-called end-of-pipe technologies (Malaman 1995:9; Overcash 1997:1304-5). Long before the 1960s smokestacks and releases into waterways were used to dilute pollution, and landfills to contain waste. The regulation now introduced built on this approach of dealing with the pollution and waste produced 'at the end of the pipe', and new technologies were developed along similar lines. An example of such a technology is the use of filters to collect and contain airborne pollution.[1]

[1] A related category of environmental innovations introduced early on are so-called monitoring technologies used to measure emissions and waste.

End-of-pipe technologies are relatively easy to add on to an existing production process, since they typically do not require any changes to core process technology. This is a reason why this type of environmental innovation was one of the first responses by firms to the new environmental regulation (Malaman 1995:9). On the other hand such innovations entail costs, but hardly any benefits for the firms, apart from an improved reputation among regulators and at times other stakeholders such as customers. Moreover, a problem from an environmental point of view is that this kind of solution may reduce some environmental impacts, but often at the price of creating new problems, since the pollution and waste is in a sense just moved around, or shifted from one type of pollution to another. For example, a scrubber can clean smoke, but the captured pollutants represent a new form of waste.

This approach to environmental regulation become increasingly discredited, and beginning in the late 70s (Overcash 1997:1301) more focus has been placed on preventing the production of waste and pollution in the first place, by modifying the basic production process. This approach has been labelled clean or cleaner technology (McMeekin and Green 1994).[2]

Cleaner technology appears to offer firms both opportunities and challenges. On the one hand waste and pollution can be seen as signs of inefficiency as they represent substances that could have been part of the product, or otherwise used profitably. ‘Pollution prevention pays’ has been a slogan of the advocates of this approach, and part of the allure of cleaner technology for business is that it holds out the promise of cheaper regulatory compliance (Overcash 1997:1305). Clean technology has been seen to represent a ‘win-win situation’ of simultaneous environmental and economic improvements.

On the other hand it may well be more difficult to introduce this kind of technological change to the extent that the production process is a configuration of

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[2] It is worth emphasising here that we are here presenting the view of cleaner technology from the perspective of environmental policy. We shall later challenge the idea of cleaner technology as new, and as subsequent to end-of-pipe technology.

We may also note that Overcash (1997:1303) lists several concepts that he claims are more or less synonymous with cleaner technology, including: pollution prevention, source reduction and cleaner production.

interdependent artefacts and routines. A cleaner technology innovation is likely to be a technologically more complex affair than adding an end-of-pipe solution. The need to integrate cleaner technologies into the production process is reflected in the alternative name of 'integrated' solutions or technologies (Kemp and Arundel 1998:3).

The belief in the win-win rhetoric of cleaner technology is also currently a part of government policies in both the environmental and innovation policy domains. The UK Department of Trade and Industry (DTI) identifies Sustainable Production and Consumption (SPC) as one of six key areas in its recent Technology Strategy, and states: "*Innovative technologies will be one of the main tools used to achieve SPC* ". It continues:

> *Energy- and resource-efficient technologies can reduce operating costs by enhancing the efficiency with which materials, energy and water are utilised, and through the minimisation of waste. They can also help to create new markets, promote competitiveness and enhance corporate reputations, whilst simultaneously providing social and environmental benefits* (DTI, 2006).

Similarly, the Environment Agency for England and Wales (EA) writes: "*Good environmental performance could save UK industry £5.8 billion every year, enhance reputation with customers and investors, drive innovation and create markets; all giving business a competitive edge*" (EA 2006:4).

Particular attention is given to contrasting so-called cleaner technology with 'traditional' end-of-pipe technology. Thus the Parliamentary Office of Science and Technology (POST) writes:

> *The traditional way to reduce the environmental impact of industry has been to fit pollution control equipment to chimneys and effluent pipes. These remove or transform releases, can recover material for recycling or reuse, and are useful for cleaning-up existing industrial processes that cannot be replaced immediately. However, they may not be sufficient by themselves to maximise resource use and minimise waste. To address this, techniques have shifted to improving products and industrial processes so that they require less raw material, water and energy, and produce less waste* (POST 2004).

Along with this emphasis on cleaner technology, there has also been a shift in recent years to consideration of the wider societal impacts of consumerism on the environment. The focus in both the end-of-pipe and the cleaner technology approaches is on the regulation of the environmental impact of production processes of individual firms, but this neglects the impact of the products produced. Increasing attention is now being paid to consumption in environmental policy, and the fact that considerable pollution, resource consumption etc. is associated with the consumption of products, and not just their production (Howells 2003; Shove 2004). It has therefore been seen as important to take a product's entire life cycle from raw materials through production and distribution to consumption and disposal into account. This is reflected in regulations targeting products, like product liability and take-back requirements (at the EU level such policies are seen as part of the Integrated Product Policy framework, Rubik 2002). For the individual firm this has sometimes meant an increasing focus on taking into account the environmental impacts of the product in the use and disposal stages, when designing and developing products.

From the regulator's point of view this approach has created new challenges. It is now less obvious which particular actors should be regulated. Responsibility for the environmental impact of a product is somehow to be apportioned among the actors involved along a product's life cycle. If end-of-pipe and cleaner technology innovations are mainly about the technology and organisation of firms, environmental product innovations are about the technology and organisation of supply chains, sectors, networks etc. The 'environmental regulation front' has thus now moved on to product life cycles and technological and sectoral systems (Kemp 1994). Another trend is the inclusion of social issues and a shift to sustainability[3] as an overall aim (see for example Griffiths and Petrick 2001).

Whilst these developments[4] are interesting and important, there are unresolved issues regarding cleaner technology and end-of-pipe technology at the firm level – as we shall see later – and this thesis will focus on the firm level and on production technology.

[3] Although 'sustainability' still often refers to environmental aspects neglecting the social ones.

[4] The shifts in environmental regulation and its focus on different environmental innovations described are not shifts in the sense of new types of regulations replacing the older ones, but rather additions of new types of regulations – and innovations – to the mix.

The belief in opportunities for win-win gains through cleaner technology at the firm level is mirrored at the policy level by a new optimism about the possibilities of achieving both economic growth and reduced pollution through 'ecological modernisation'. This can also be seen as part of a broader move towards economic and market-based instruments in environmental policy, thus emphasising the economic aspects of pollution and of pollution prevention. And, insofar as win-win opportunities are seen as implying that firms would act voluntarily to prevent pollution, the notion also fits well with de-regulation agendas.

1.1.3 Ecological modernisation versus green Marxism

The newfound optimism also reflects a development in the environmental movement from radical outsider-activism, to a more pragmatic stance including cooperation with government and industry. As environmental movement organisations orientated towards protest have been complemented with more moderate activists as well as mainstream political parties, a more pragmatic way of understanding the societal background of environmental degradation became established – and was articulated as ecological modernisation theory (Hajer 1996).

The academic theory of ecological modernisation embodies the belief in win-win solutions – both at firm and society level – with its central claim that societal institutions can integrate ecological with economic rationality. The theory thus promises to explain the societal dynamics leading to the integration of environmental concerns into technological decision-making.

We shall here describe the theory of ecological modernisation in somewhat greater detail to see what it has to say about environmental innovation in firms. To assess whether the optimism regarding the possibilities of integrating ecological and economic rationalities of ecological modernisation theory is warranted, we shall also contrast it with a more sceptical theory: green Marxism.

Ecological modernisation theory states that it is possible to reform institutions to substantially reduce environmental problems – and even that this is a probable future

(Spaargaren and Mol 1992:334). The mechanism through which this is to take place is the integration of ecological rationality, so that decisions made take the environment into account.[5] 'Ecological rationality' here means a normative, action-orientated way of thinking, and presumably presupposes at least a degree of ecological knowledge.

Ecological rationality is in ecological modernisation theory seen to be compatible with economic rationality. The proponents of the theory want to ecologise economic institutions, and "*economiz[e] ecology by placing an economic value on the third force of production: nature*" (Spaargaren and Mol 1992:335). The authors are also optimistic regarding the possibilities of new, cleaner technologies embodying this integration of ecological and economic rationalities. In particular generic technologies like information technology, biotechnology and materials technology are said to offer potential for environmental improvement.

The role of the state in this theory is not clear. Some proponents have varyingly stressed the voluntary adoption of ecological rationality by industry, whereas others have claimed a role for the state in regulating industry, although through flexible, market-based policies rather than more heavy-handed command and control policies (Spaargaren and Mol 1992:335, 340). Murphy and Gouldson (2000:33), applying ecological modernisation theory to a study of regulation and industrial innovation, found support for the idea that regulation can stimulate innovation, and they stressed the knowledge contributions of pollution inspectors to firms.

Ecological modernisation theory has been criticized at a theoretical level by green Marxists for neglecting structural barriers to environmental improvement in society (Mol and Spaargaren 2000:22). Drawing on empirical work (on the UK refrigeration industry), and backed by Marxist theory, Purvis *et al*. (2001:154) criticized ecological modernisation theory for over-stating the rational behaviour and the potential of knowledge access and cooperation of firm actors.

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[5] Ecological modernisation is in this sense not dissimilar to the reflexive modernisation concept of for example Ulrich Beck (1994).

Green Marxism is not the only theoretical approach that is sceptical of the ecological modernisation view of the relationship between the environment and society. However, other approaches (for example ecofeminist theory and risk society theory) do not deal with industry as central to society. 'Green Marxism' is here used as a label for a variety of texts, written over a period of about 30 years. There are large variations within this school of thought, and we shall here certainly not try to give a comprehensive overview. This is, however, not necessary to give an effective contrast to ecological modernisation theory.

Most green Marxist contributions conceive a more problematic relationship between the environment and the economic sphere than does ecological modernisation. At the core of green Marxism are (ecological) contradictions between the capitalist requirement for profit (Benton 1989:72) and ecological considerations. As early as 1972 Commoner traced industry's propensity to cause environmental damage back to its ability to externalise environmental costs (Commoner 1972:252). Gorz – writing in a different strand of Marxism – sees the hegemony of instrumental rationality in industrial society as the core problem (Gorz 1993:56-57). Both contributions share a sceptical view of industry's voluntary adoption of ecological rationality.

Where ecological modernisation sees an alliance between moderate greens and state bureaucracy as an important locus of the new ecological rationality, green Marxism would place more hope with radical green movements struggling outside the establishment, preferably in alliance with labour (O'Connor 1996:201).

As compared to ecological modernisation, and in line with a weaker belief in voluntarism, green Marxists tend to stress more firmly the importance of state intervention (O'Connor 1996:2001) (although again this varies, depending on whether the state is seen as an instrument of capital, or a more free-standing arena).

Green Marxist writers have varying views of technology and its potential contributions to solving environmental problems. Few green Marxists would be as optimistic about technology as ecological modernists, however. Perhaps Bridge, writing based on an empirical study of copper mining in the US, best captures a typical Marxist position. He asserts that innovations – technological, organisational, or institutional – do not transcend the ecological contradictions, but rather serve to generate more effective ways of managing them (Bridge 2000:253).

Neither ecological modernisation nor green Marxism is very explicit about organisational issues, about what goes on inside firms. But from our description of the theories above we may extrapolate. Ecological modernisation is more likely to support a smooth (and perhaps even voluntary) uptake of ecological rationality in firms, and sees no inescapable limits to this integration. In green Marxism we would expect to see clashes with, the ultimately dominant, profit rationale.

This raises questions about how ecological rationality[6] is taken up by firms; how it fits or clashes with other – particularly economic – rationalities; and whether there are limits to the uptake of ecological rationalities. Moreover, a view of cleaner technology as embodying win-win solutions – and thus the integration of ecological and economic rationalities – is highly compatible with ecological modernisation. If, however, cleaner technology does not deliver on this promise, and if the contradictions between ecological and economic rationalities remain, then one of the central underpinnings of ecological modernisation will look shaky, and the Green Marxist perspective will be accordingly strengthened.

1.2 Aim and research strategy

This section will specify the aim of the thesis. We shall also introduce the research questions, and, finally, a brief description of the methodology (a more comprehensive account is given in chapter 4).

1.2.1 Aim

Cleaner technology is being promoted in both political and academic discourses as a means of simultaneously achieving environmental improvements and economic

[6] We do not mean 'rationality' in the normative sense, that is, as an opposite to irrationality. Instead it here means a way of thinking about a certain topic in a particular cultural context, and we see the possibilities for multiple rationalities, in particular ecological and economic ones.

gains. Cleaner technology is thus thought to provide so-called 'win-win' opportunities, and circumvent conflicts between environmental and other 'business-as-usual' (BAU) commercial motives (cost, profitability, product quality, resource efficiency, etc.).

It has, however, been observed that cleaner technology has yet to deliver on a large scale on this promise, and that the uptake of cleaner technologies has been limited (Clayton *et al*. 1999:2). Explanations for this have also been put forth. It has been claimed that cleaner technologies are generally newer than end-of-pipe technologies, and therefore less optimised, less well-known etc., which may in turn discourage adoption (Malaman 1995:2). Clayton *et al*. (1999:230, 251) have also shown, for example, that regulatory demands of too large and rapid environmental improvements risk pushing companies to invest in end-of-pipe technology rather than cleaner technology, and that if environmental staff dominate the investment process, there may be a lock-in to end-of-pipe technology.

Existing accounts of cleaner technology have thus focussed on comparisons with end-of-pipe technologies, but fail to compare cleaner technology with 'non-environmental technology', that is process technologies that are not considered to be 'environmental' – let us call them BAU innovations – in a systematic way, and to explore this distinction.[7] The existing accounts are therefore asymmetrical in the sense that they explain environmental technology, but not BAU innovations. In the area of environmental management literature, this is mirrored empirically by a bias towards studies of so-called 'best practice'.[8]

The existing accounts also fail to distinguish clearly between environmental intentions and environmental outcomes. This means that there is a risk of taking the environmental properties of the technologies for granted (reification), rather than examining how their 'environmental-ness' is constructed throughout the innovation

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[7] Clayton *et al*. (1999:237) note that when resource efficiency concerns are already well entrenched it is difficult to distinguish between cleaner technologies and what is otherwise considered good engineering practice, but do not explore this further.

[8] With the intention to show what is possible and in the hope that such 'good examples' will be compelling enough to change actual practices. See for example Zwetsloot (1995:64) and Handfield *et al*. (2001:189).

process.[9] We need to ask how a technology comes to be seen as delivering environmental improvements, and not just accept the label 'environmental' as presented to us. This means that we need to unpack the innovation process, and study how environmental intentions are articulated in decision-making.

The distinction between intentions and outcomes is also blurred when the focus is on good (that is intentional *and* successful) examples of environmental innovation – but would become more urgent if BAU innovations were to be studied as well. Reification and asymmetry thus go hand in hand.

These problems – asymmetry and reification – raise doubts about our understanding of cleaner technology, and the claims made about it. We must ask ourselves again what cleaner technology is. Can cleaner technologies be distinguished from BAU innovations? Does it make sense to say that cleaner technologies deliver win-win solutions? And if these basic facts are questioned, other claims made about cleaner technologies, that is, that they are newer than end-of-pipe technologies, and that the up-take has been low, may have to be revisited as well.

The aim of this thesis is therefore: to explore the concept of 'cleaner technology' through comparison with 'BAU innovations', and through studying the role of environmental intentions articulated in decision-making in innovation processes, in order to set out an understanding of the topic that avoids reification and asymmetry, and is useful analytically and for policy.

There is also a more personal background to the topic of this thesis. Before starting out on this research project, I already had an interest in environmental innovations, as a way of combining my interests in environmental and technological issues. As part of my previous work in Sweden, I had done a study of environmental innovation literature and noticed that there was something strange about how the concept 'environmental innovation' was defined in terms of either environmental intentions or environmental outcomes (Markusson and Olofsdotter 2001:14-15). It seemed to me that environmental intentions and outcomes need not coincide, and that the concept was therefore ambiguous.

[9] We shall discuss these claims in more detail and back them up in chapter 2.

When looking for a PhD position I encountered the Science and Technology Studies (STS) approach at Edinburgh University, and it seemed to offer a good way of understanding technology and innovation, which also chimed with my general political, conflictual view of society. When later reading the literature on environmental innovations, it became obvious that a large part of it was done by researchers with quite different commitments from those prevalent in STS, and the project came to be in part about how to understand this difference.

During the course of planning the research a choice also had to be made whether to focus on the organisational level or the meso-level of technological systems/industrial sectors. Either avenue could quite possibly have proved fruitful in probing the issue of intentions and outcomes, and the choice of focussing on the organisational level was made based on a (more or less accurate) idea of wanting to study the 'reality' of the micro setting. Here I could study people – and not just organisational actors – with their knowledge, roles and interests. A political approach to studying organisations appeared to both match my interests, and to offer promising avenues of research on this topic.

At this more personal level this thesis is therefore also about bringing STS and organisational politics literature to bear on an area of research dominated by environmental management literature.

1.2.2 Research questions

It follows from the discussion above about the aim of this thesis that we do not know enough about how environmental intentions shape technology and environmental outcomes in innovation processes. Since we intend to focus on comparing cleaner technology with BAU innovations, we are especially interested in 'core' rather than end-of-pipe technology. Our first research question is therefore:

1. *What is the impact of environmental intentions on the technological outcomes, especially on core technologies?*

We also saw that we need to unpack the innovation process and study how environmental intentions are articulated and how they impact on the decisions made as part of the innovation process in firm organisations. Little existing research in the area of organisation and environmental innovation has been done from the perspective of organisational politics, which is a likely explanation for some of the gaps in our knowledge. The main gaps identified (as discussed in more detail in chapter 2) are:

- Relatively little is known about the roles and contributions of engineers and environmental staff in this context, and about the relationship between these two actor categories.

- There is also a lack of knowledge about how environmental intentions fit with other strategies and motives behind technological change in firms, and in more concrete terms how environmental intentions fit with the interests and agendas of the actors in the firm.

- Finally, not enough is known about structural limits to the integration of environmental concerns into firm organisations, and how such structures can be changed.

We thus need to know more about how decisions are made in innovation processes. We need to know why any firm actor would promote environmental concerns and under what circumstances environmental concerns are successfully promoted in this context. Our second research question is therefore:

2. *How do any environmental concerns that firm actors may have affect the decisions made in innovation processes?*

And, relatedly, we need to understand the organisational context in which the promotion of environmental concerns in innovation work may happen. This raises questions about how the organisational structures affect decision-making. Especially if these structures limit the opportunities for successful environmental promotion then we need to know why that is so and when and how these limits can be shifted. The final research question is therefore:

3. *What are the structurally determined organisational limits and opportunities to the integration of environmental concerns into firm innovation processes?*

1.2.3 Methodology

Having set out the research questions, we need to develop a methodology that will enable us to answer these questions. The methodology will be introduced in this sub-section (and more thoroughly in chapter 4). First we discuss why a cases study approach was chosen. Thereafter data collection is presented, and, lastly, the analysis.

This research is – at a general level – about making peoples' everyday experiences accessible to academic reflection, about providing concepts and categorisations that reflect people's lives, but that also form a systematic framework capable of generalisation. The wish to gain access to people's own understandings of their situation and to analyse this within a complex setting calls for a case study approach capable of dealing with the required richness of data (Yin 1994:13).

This thesis sets out to understand the decisions made as part of innovation processes, and their background in the interests of the actors, given the context of the firm organisation and the wider societal context. The unit of analysis was thus chosen to be the technological choices made relating to an investment project.

Analytical leverage was sought from a comparative perspective. Deliberately contrasting case selection may shed light on the influence of the differing characteristics of the cases ('theoretical replication', Yin 1994:48). Cases were selected in different industries as well as in different countries. The chemicals industry was chosen for its obvious relevance to environmental issues, but also for its relatively long history of exposure to environmental regulation, and supposed well-developed capabilities of responding to regulation. As a contrasting case the dairy sector was chosen, with its typically less harmful waste streams and weaker exposure to regulation. By delimiting the study to process industries comparability between sectors is enhanced. Cases were also drawn from Scotland and Sweden. It was hoped that differences in regulatory regimes as well as in general public commitment to environmental improvement would enable useful comparisons.

We have consciously avoided studying only ‘best practice’ cases, to avoid an asymmetrical analysis. Both cases where environmental motives were central and more peripheral (as claimed by the initial contacts in the firm) were selected. This was also thought to help against reification of environmental intentions, in that we thus avoid presupposing that environmental innovation is a distinct and separate category of innovation, and instead study the role of environmental intentions in cases with varying degrees of environmental ambition and outcomes. The cases selected were mainly focussed on core technology, but also included to a smaller degree end-of-pipe technology.

Data was collected primarily through semi-structured interviews, suitable for the complex and contextualised nature of the topic (May 1993:93). Most interviews were performed visiting the companies in question, although a minority of interviews were done via telephone. All interviews were transcribed and sent to the interviewees for comment.

The main categories of interviewees are managers, engineers and environmental staff in the companies that had a role in the investment projects. To find as many of these three categories of interviewees as possible in each case, small companies were avoided. Small investment projects with few employees participating were also avoided for the same reason.

Apart from these interviewees, all cases apart from one also include consultants and/ or suppliers doing work that would otherwise have been done by firm employees. Consultant and supplier staff were also interviewed when appropriate. Lastly, interviews were made with staff in regulatory agencies to gain a potentially different viewpoint from the one of the firm regarding the environmental aspects of the investment projects.

The major interview themes were: the projects, the choices made, the actors involved, the internal organisational context and the external context of the companies. Efforts were made to elicit information both on the period of the project and the history of the organisations and the individuals before that.

The cases were written up as case stories (Yin 1994:104), focussing on the decisions made and the roles of the actors in the innovation process. An important part of the analysis is comparing the cases. Clear differences were for example found between the chemicals and the dairy cases. But the cases also have strong similarities, and some of the analysis is made across the cases.

1.3 Structure of the thesis

In the next chapter we shall review the existing literature on environmental innovations. The chapter starts off with a discussion of the role of regulation and other drivers of environmental innovation. It is possible to distinguish between environmental innovation literature that deals with firm organisation and literature on firms as wholes. The latter stream of literature is first reviewed and some problems with this literature are outlined. Thereafter, the literature on environmental innovation and firm organisation is reviewed.

Chapter 3 sets out the theoretical framework of the thesis. In its first section a political approach to firm organisation is introduced, and contrasted with a managerial perspective. Special attention is given to the interests and expertise of firm actors. In the second section the political perspective is applied to the area of environmental process innovation. After first discussing different perspectives on the innovation process, this section is organised around the themes of environmental promotion (action) and the company social constitution (structure). Throughout the notion of integration of environmental motives into innovation processes is elaborated. Thereafter, in chapter 4, the methodology of the thesis is set out, as more briefly described above.

Chapter 5 gives a background to the case studies in terms of the two country settings: Scotland and Sweden, with special attention given to environmental attitudes, regulatory regimes and occupational formation regimes. Also, the chapter introduces the two sectoral settings: the chemical industry and the dairy industry. The sectoral settings are described in terms of markets, technology and environmental aspects. The main empirical foundation of the thesis is presented in chapters 6 and 7, with the four case studies of the environmental aspects of investment projects in four firms. Two case studies are of chemicals firms and two of dairy firms. One case study in each sector is in Sweden and one in Scotland.

In chapter 8 the data is analysed. The first section deals with the relationship between environmental staff and engineers, and the formers' roles in the company and its innovation processes. Thereafter follows a section on environmental champions, based on analysis of careers and championing events. The third section discusses the relationship between environmental intentions and technological outcomes, with a focus on core technology, but also – to a lesser extent – end-of-pipe technology.

Finally, in chapter 9 the findings are summarised before setting out the main theoretical contributions of the thesis. Furthermore, some implications for practice are presented. This chapter also discusses some methodological implication and limitations to this thesis, and presents some ideas for further research.

2 The organisation of environmental innovations

As suggested in chapter 1 there are problems in the existing literature on environmental innovations, and especially when it comes to the notion of 'cleaner technology'. We there concluded that we need to compare cleaner technology with other core technology innovations, and unpack the innovation process to study how environmental intentions are articulated in the decisions made as part of it. We shall here discuss these issues in more depth.

The chapter starts with a discussion of literature on environmental innovations that conceptualises the firm as a whole. We shall address the theme of environmental regulation versus voluntary firm action, and based on this problematise the concept of 'cleaner technology'. Thereafter follows a discussion of problems in the literature on environmental innovation, as seen from an STS (Science and Technology Studies) perspective. Building on the discussion of these problems and a review of the literature on environmental innovation and firm organisation, we shall – finally – draw conclusions regarding what knowledge gaps there are.

2.1 What are environmental innovations?

An important goal of this thesis is to understand the role of environmental motives in innovation processes. We shall in this section first discuss the impact of environmental regulation as a driver motivating environmental improvement through innovation, and contrast this with the idea of voluntary (that is not compliance driven) innovation. This will serve as an introduction to a discussion of the concepts of 'environmental innovation' and 'cleaner technology' and what motivates firms to undertake such innovation.

2.1.1 Environmental regulation, the firm and voluntary action

As mentioned in the introductory chapter, end-of-pipe technology as a response of firms to environmental regulation has been discredited, and increasingly hope has instead been set to cleaner technology solutions. The economic effects of environmental regulation on firms have also been debated, not least in terms of the effects on firm profitability and, by extension, on economic growth and employment levels. Porter and van der Linde (1995) challenged the existing consensus among economists that environmental regulation increases costs for firms and thus reduces their competitiveness, and instead proposed that regulations induce firms to undertake environmental innovations that may increase their competitiveness. Underlying this debate are differing views of the role of technology in business. Porter[10] draws on business studies (and evolutionary economics) with its understanding of innovation and technological differentiation as a strategy to create competitive advantage, as compared to the mainstream view in (neoclassical) economics where technology is available to all and firm competitiveness is built on efficiency and reduced costs.

By extension this debate is also about the possibility for environmental improvements by regulation. It may be argued that if firms are commercially hampered by heavy-handed environmental regulation they may lose out in competition, and ultimately go bankrupt, in which case an improved environmental performance will not help. In contrast, Porter claims that regulation can both improve environmental performance and lead to more competitive firms, a so-called win-win solution.

We can ignore the discussions on conceptual and statistical problems in the unresolved debate in economics (see for example Palmer *et al.*, 1995) regarding Porter's arguments, but it is worth noting that his ideas are part of a broader statement that better environmental and economical performance can be mutually reinforcing and should be simultaneously achieved. That is, Porter's ideas mirror ecological modernisation theory.

Some authors have taken the win-win idea one step further, stressing the voluntary action of firms undertaking environmental innovations. A weak version of this argument is that some firms will innovate in advance of expected new regulation to

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[10] The debate is commonly referred to as the Porter debate. I will follow this convention, in spite of the contributions of, for example, van der Linde.

capture first-mover advantages – so called proactive compliance (Aragón-Correa 1998; Marshall *et al*. 2005).

A stronger version of the argument does away with regulation altogether: if there is a business case of environmental improvements offering economic benefits, then environmental innovations will be undertaken regardless of any regulation (Meredith and Wolters 1994:25).[11] The original position of, for example, Porter – that while environmental innovations do entail costs, they can sometimes also make business sense – has here been virtually inverted. It is not only the case that environmental innovations can sometimes make economic sense, but, it is claimed, they generally do offer larger economic benefits than costs.

These arguments refer primarily to cleaner technology. There are even some definitions of cleaner technology that include business opportunities as part of what constitutes cleaner technology (McMeekin and Green, 1994).

There is plenty of evidence on which to base a discussion of these matters. Survey-based studies of stakeholders and of the motivations behind environmental innovations provide important sources here. These studies have shown that regulators are not the only important actor driving environmental improvements, and that market conditions may drive environmental innovations as well as regulation (Madsen and Ulhøi, 2001; Polonsky and Ottman, 1998). A longitudinal study by Heidenmark suggests that regulation used to be the main reason for environmental improvements, but that that is no longer the case (Heidenmark, 1999:32).

The evidence tends to confirm that regulation still matters, but that there are also other important driving forces. The claim that regulation does not matter at all any more is not confirmed by the survey data. It is also worth noticing that there is a

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[11] Note that there are two interpretations of what the win-win argument actually says. One of the ‘wins’ is about economic benefits (profits, cost savings, etc.), but the other ‘win’ is either regulatory compliance or environmental improvements. The strong version of the voluntary action argument stresses environmental improvements irrespective of compliance with regulation, whereas the weak version of the argument refers to compliance rather than environmental improvements per se.

Meredith and Wolters start off investigating proactivity, but discover a dynamic that goes beyond proactivity, with market forces controlling the modernisation process, and governments playing only an initiating role. The authors make explicit reference to ecological modernisation theory.

difference between environmental process and product innovations: the latter are typically driven more by market dynamics and less by regulation than the former (Green *et al*., 1994).

There is a methodological problem with these studies in that they distinguish between regulation and markets drivers as seen from the viewpoint of the individual firm. It may be that one would get a different picture looking at sectors at a system level. If, for example, a supplier meets environmental demands from a customer company, this may in turn be due to regulatory demands on the customer firm. This type of dynamics may not be visible from the perspective of the supplier answering a survey. The effect of regulation in creating demand may thus be underestimated. This shows that disentangling markets from regulation may be difficult (see Emtairah *et al*., 2002, for an interesting effort to study the creation of markets for goods with an environmental profile). There are of course cases where consumers or other buyers take the environment into account without being prompted by regulation, but for many products this is not the case. The point here is that we should remain sceptical of these studies as evidence of an increasing market dynamic supporting environmental innovation that is independent of regulation. This argument is supported by Green *et al*. (1994), who found a correlation between regulation and market factors, and by Foster and Green (2000), who saw that regulation was an important driver of customer demands.

Another problem with the win-win argument is that if environmental innovations offer these economic advantages to firms, then why do we not see more of them? There have, certainly, been improvements over the last 30 years in terms of reduced pollution from firms, and yet it still is a substantial problem (Richards *et al*. 204:389), and surveys appear to show that many firms do not engage in environmental innovation (see SCB 2000 for the case of Sweden).

The win-win argument does not require firms to adopt wholeheartedly an ecological rationality; it is enough that they respond to regulation. Responding to regulation requires attention to environmental aspects of production, and is in this sense a source of ecological rationality. (The strong, voluntarist version of the win-win argument does, however, suppose that this happens spontaneously.) And conscious efforts to improve environmental improvement may – as we shall see in the next section – help firms to spot win-win situations and opportunities for cleaner technology.

2.1.2 Conflating intentions and outcomes

The background of the concept of 'environmental innovation' in environmental policy, as described in chapter 1, reflects a desire to see firms doing something differently to what they would otherwise have done. That is, it highlights the *intention*[12] to achieve environmental improvements. The concept of environmental innovations also relates, however, to the *outcome* of environmental innovations in terms of the handling of pollution and waste, the prevention of pollution and waste etc.

This distinction matters because motives other than environmental ones may drive investments in cleaner technology. In particular, resource efficiency is an important driver for cleaner technology (Malaman 1995:2). Inefficiencies are costly and resource efficiency is an important goal in itself for many firms. It may be the case that no one in the firm thought about the environmental gains following from resource efficiency improvements (Clayton *et al*. 1999:268). The environmental improvements may thus be unintentional and unrecognised side effects of increased resource efficiency.

There is thus an ambiguity in the concept of environmental innovation between intentions to improve environmental performance, and the outcomes of innovation. Many researchers of environmental innovation have neglected this; the definitions given vary, but not in explicit recognition of this ambiguity. It is often impossible to tell which of these two bases the definition is meant to rest on, and sometimes an assumption is made that intentions and outcomes coincide. For example Murphy and Gouldson (2000:36) define cleaner technology as "*general processes or products*

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[12] 'Environmental intention' here refers to conscious efforts to improve environmental performance *irrespective* of why the firm wants to do this. A dominant cause is, as we have seen, regulatory compliance, but the term does not exclude other possibilities, like market demands, or even any ethical twitches.

which fulfil a non-environmental objective as their primary purpose but which integrate environmental considerations into their design to avoid or reduce their impact on the environment". This can be compared to the definition given by del Río González: "*changes in production processes that reduce the quantity of wastes and pollutants generated in the production process or during the whole life cycle of the product*" (2005:22), which appears to be outcome-orientated.

Sometimes the lack of attention to this distinction causes problems. Del Río González also defines environmental technology as "*any technology that drastically reduces environmental problems and that has been adopted mainly for that reason*" (*ibid*.:29), which refers to both intentions and outcomes. Having thus stated that environmental motives are the main motives behind environmental technology adoption (per definition) the author goes on to say that economic motives played a very limited role (*ibid*.:30). This would have been a simple case of circular reasoning had it not been for the fact that the author also states that economic motives are important for cleaner technology adoption (*ibid*.:30). This confusion is based on a lack of clarity as to what the relation is between intentions and outcomes, and how innovations were chosen for this study.

Failure to appreciate the distinction between intentions and outcomes can have serious implications for the way that studies on environmental innovations are carried out. For example, Hilliard (2001:22) has claimed, in a study of how organisational capabilities of pharmaceutical firms relate to their environmental innovations, that there is no correlation between a firm's process development capability and its propensity to undertake cleaner technology (as opposed to end-of-pipe) projects. This result is counter-intuitive and goes against the findings of other authors (Clayton *et al*. 1999:251).

However, the study by Hilliard is based on data reported to the Irish Environmental Protection Agency, and it is likely – but not made explicit – that what is reported here as cleaner technology projects excludes projects where environmental concerns were not central to the innovation. Effectively then the innovations studied are delimited by intention (as well as outcome). This is in line with the aim of the study which was to analyse the impact of regulation, and the definition of cleaner technology given is "*approaches to manufacturing that minimise the generation of harmful waste and maximise the efficiency of energy use and material use*" (*ibid*.:4), which appears to include intentions as well as outcomes.

Hilliard argues that her finding shows that in general process development and environmental management are not connected (*ibid*.:23). And whilst this may well be true, it is still unlikely that process development capabilities are irrelevant for the uptake of cleaner technology. Questions arise about exactly what projects were reported to the Environmental Agency, and what the results of the study would have been has its scope been set differently.

These examples illustrate why it is important to be explicit about whether we are talking of environmental intentions or environmental outcomes when studying environmental innovations, that is, how we define the concept. We should avoid conflating environmental intentions and environmental outcomes, and instead analyse them as separate phenomena.

The examples also show that definition by intention or outcomes matters for what innovations we should choose for study. If we are primarily interested in the role of environmental intentions we may want to select environmental innovations as defined by intention, but then we shall miss those innovations that are driven predominantly by other, for example resource efficiency, motives. If, in contrast, we are interested in all sources of environmental improvement, then we need to study all innovations that improve environmental performance, irrespective of intentions.

2.1.3 Cleaner technology as reification

The distinction between intentions and outcomes plays out somewhat differently between end-of-pipe and cleaner technology. We shall here discuss these two types of environmental innovation, and criticise a tendency to reify cleaner technology, that is, to assume that environmental properties are inherent in cleaner technologies.

Cleaner technology can, as we saw in chapter 1, be defined as changes to production processes so as to avoid the production of pollution and waste. It may also be defined to include for example input substitution. The common factor among different definitions is the avoidance of pollution production, as compared to collection and treatment with end-of-pipe technologies.[13]

It is thus often assumed that there are two main categories of technology available for environmental process innovations: end-of-pipe and cleaner technology. Cleaner technology is often thought of as an alternative to end-of-pipe technology, but the concepts are in a sense quite different. Whereas end-of-pipe technologies are to a large degree a discernible set of technologies: filters, treatment plants, etc., cleaner technology is a relative concept. Any technology used in a production process could in principle be labelled cleaner depending on what alternative it is compared to. For example, a new production control system may improve environmental performance as compared to a previous system by reducing the waste produced (per unit product), and so deserve the label cleaner technology (as defined by outcome). Its 'clean-ness' thus lies in a comparison with the environmental performance of another technology, and this property needs to be judged for each particular innovation case.

It is however not quite clear what technology to compare with. Malaman proposes that cleaner means cleaner than "*the dominant technologies in the period under consideration*" (1995:1), which implies a general, or perhaps a sector level, comparison. But he also defines cleaner technologies as "*all the modifications in processes and products which reduce impact on the environment, as compared to the products and processes which they have substituted*" (*ibid*.:2), which appears to be a more situated definition, suggesting that the comparison is to be made at the firm level.

In practice some technologies are more likely than others to offer opportunities for environmental improvements for a particular type of production process at a particular point in time. For example, Cesaroni and Arduini (2001:10) list what they perceive to be current cleaner technological trends in the chemicals industry (see table 2.1). It is however unclear how the authors have identified these technologies,

[13] It is also worth noting that there is a grey zone between cleaner technology and end-of-pipe in the case of recycling, where a waste product is linked back into the production process to become a useful input.

and it seems unlikely, for example, that all biological processes always produce less pollution than all non-biological alternatives.

Table 2.1 Cleaner technology trends in the chemicals industry

Application	**Technology**
Plants	Continuous reactors, low temperature separation processes, continuous fluid bed processes, safety systems: e.g. control procedures
Chemicals	High-selectivity reactions, reactions producing recycling by-products, biological processes

Source: Cesaroni and Arduini (2001:10)

It appears problematic to identify and list cleaner technologies. The same authors discovered that they could readily identify patents of end-of-pipe technologies, but not of cleaner technologies (*ibid*.:48). They also noticed that they could identify suppliers of end-of-pipe technologies, but not of cleaner technologies (*ibid*.:63). This illustrates the difficulty of identifying cleaner technologies out of the context of the particular innovating firm.

This difficulty is connected to our discussion of intentions and outcomes. There is a sense in which end-of-pipe technologies embody environmental intentions in a way that cleaner technologies do not. End-of-pipe technologies typically do not offer the adopting firms any economic advantages, and whilst Clayton *et al*. have shown that regulatory compliance is not the only motive for their adoption (1999:251), it seems very unlikely that they would be considered without any reference to environmental performance. By contrast, as we have seen, cleaner technologies may well be adopted without considering their contribution to environmental performance.[14] End-of-pipe technologies are therefore likelier to be patented and sold as offering environmental benefits.

[14] Clayton *et al*. found an example of the impetus for the introduction of a particular cleaner technology being environmental motives in one company and economic motives in another (1999:268).

End-of-pipe technology can therefore reasonably be described as a universal class of technology with an environmental function, whereas the clean-ness of cleaner technology is more clearly a situated property in a particular adoption context.

This is neither to say that any particular end-of-pipe technology is always the best environmental option in a given situation, nor that end-of-pipe technologies will always work. Their clean-ness also needs to be constructed in a particular setting, but they seem always to come packaged with an idea of clean-ness.[15] In contrast, to talk of cleaner technology as a class of technology is to impute this environmental property where there may be none.

The clean-ness of cleaner technology is thus not built into particular technologies in the same way as the clean-ness of end-of-pipe technologies. Spinardi *et al*. (1998:3) have pointed to this difficulty of packaging cleaner technologies into easily adaptable and transferable black boxes. Relatedly, Cesaroni and Arduini note that cleaner technology is difficult to standardise into specialised products provided by a specialised sector (2001:66).

End-of-pipe technology is in this way a successful reification of environmental intentions, whereas cleaner technology is more difficult to 'blackbox' (Scarbrough 1995:1006). Cleaner technology is therefore a somewhat misleading concept. It would perhaps be better to talk of 'cleaner innovation' than 'cleaner technology' to stress that it is a situated activity rather than a universal class of technology,[16] and see core technology rather than cleaner technology as the opposite to end-of-pipe technology.

This still leaves us, however, with the issue of definition by intention or outcome. We need also to distinguish between 'intentional cleaner innovation' and 'unintentional cleaner innovation' (both of which may draw on the same technology). This distinction is unnecessary for end-of-pipe innovation.

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[15] Relatedly, core technology investments will normally be subjected to a pay-back evaluation, whereas end-of-pipe technology as a response to regulation may avoid being given such explicit economic valuation and instead be seen as a stay-in-business investments (Clayton *et al*. 1999:255).

[16] This also makes the concept more similar to alternatives like 'cleaner production' or 'pollution prevention'.

We can now return to the issue raised in chapter 1 of whether cleaner technology is newer than end-of-pipe technology. Often cleaner technology means cleaner than the technology it replaces (Malaman 1995:2). Malaman here refers to the firm level, but it would appear to be valid also on a higher level, say a sector.[17] This means that as more efficient technologies are developed for a particular type of production (whether motivated by environmental concerns or not) they can be labelled cleaner technology. In this sense cleaner technologies are likely to be comparatively new. But it also means that what is called clean technology today may not be called that tomorrow.

Murphy and Gouldson claim (with reference to the OECD, DTI, etc.) that cleaner technology adoption has been hampered by end-of-pipe technologies being older and having benefited more from scale and learning effects. "*In many instances, clean technologies have yet to benefit from a similar process because they have been less widely adopted*" (2000:36). But this appears to be a dubious explanation. As the relatively new cleaner technologies are developed further drawing on experiences from their adoption, they may well be overtaken by newer technologies and so lose their status of being cleaner, rather than becoming more competitive vis-à-vis end-of-pipe technologies. The view of the development of cleaner technologies of Murphy and Gouldson is based on the mistake of seeing cleaner technology as a universal class of technology in the same sense that end-of-pipe technology is.

Murphy and Gouldson are in a sense right that cleaner technologies are generally new, but for the wrong reasons. Cleaner technologies tend to be new technologies, since they lose that status when even cleaner technologies are developed, not because they are a newly developed and unproven special class of technology. Moreover, end-of-pipe technology is not static. New such technologies are also developed, adding to or replacing the already existing ones. It may be that on average, cleaner technologies are newer than end-of-pipe ones, but this obscures large variation.

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[17] Indeed, it may be that 'cleaner technology' makes more sense on a sector level than on the firm level. It seems likely that particular technologies will offer firms more opportunities for win-win solutions than other technologies as compared to the technologies *typically* used in the sector at a particular point in time. 'Clean-ness' here becomes a 'statistical' property. Individual firms may adopt such technologies for different reasons that may or may not include environmental improvement. It is, as we have seen, difficult to blackbox cleaner technologies.

From this line of argument it also follows that there have always been cleaner technologies, in the sense of technologies that were more resource efficient than what came before. Cleaner technology is in this sense not a new thing, and probably rather older than end-of-pipe technology. What is likely to be new is intentional search for cleaner technological solutions, that is, intentional cleaner innovation,[18] and the very idea that this is possible.

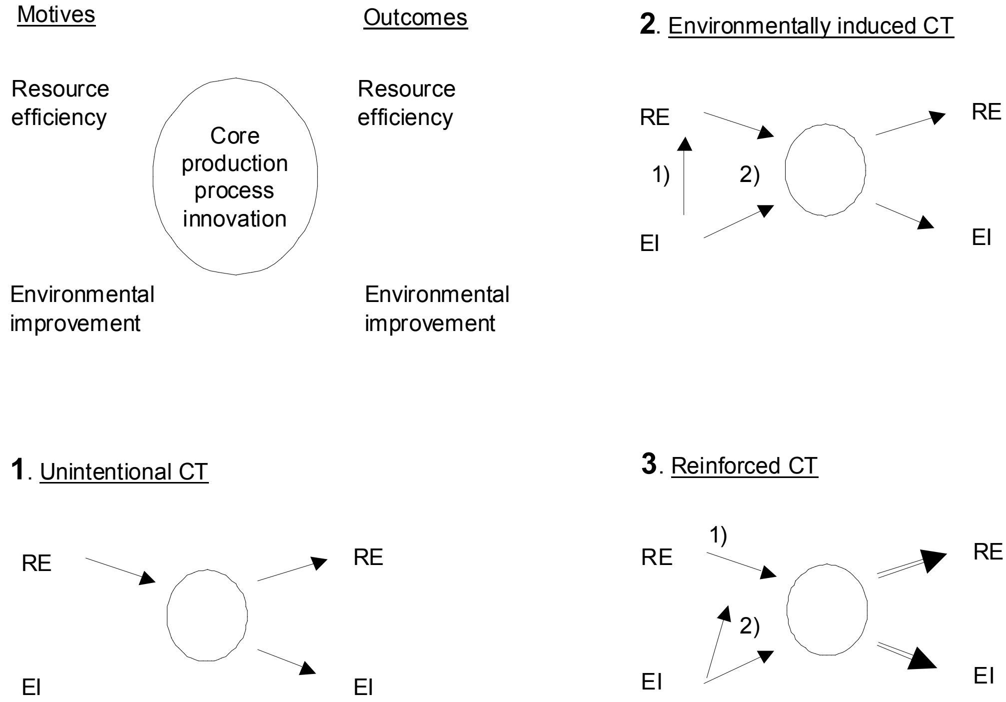
2.1.4 The role of environmental intentions

We have seen that the distinction between environmental intentions and environmental outcomes matters when studying environmental innovation, and in particular cleaner innovation. We have also seen that other motives than environmental ones, not least resource efficiency, may motivate firms to undertake cleaner innovation. Environmental motives may even be absent as in the case of unintentional cleaner innovation (see diagram 1 in figure 2.1).

The question then arises what the role of environmental motives is when there are also other motives for technological changes that improve environmental performance. What is the relationship between the different motives?

[18] And intentional cleaner innovation is probably somewhat newer than 'end-of-pipe innovation'.

Figure 2.1 Cases of cleaner technology innovation[19]



Note: 'RE'=resource efficiency, 'EI'=environmental improvement, 'CT=Cleaner technology.

Clayton *et al*. (1999) have shown that intentional efforts to improve environmental performance may uncover resource efficiency opportunities hitherto unnoticed. Scrutinising existing operations from an environmental perspective may generate new knowledge about them, thus revealing new opportunities to improve resource efficiency. The authors describe this as an 'information inductance' effect where new evaluation criteria generate new knowledge which in turn may lead to the identification of new opportunities (*ibid*.:248). This is schematically depicted in diagram 2 in figure 2.1 as environmental motives generating resource efficiency motives, both of which subsequently support a proposed innovation.

[19] Reality is likely to be less linear than what these figures imply. We will return to that issue in the

The diagram is also a simplification in that it excludes other motives than resource efficiency and environmental improvement. The overall argument is however not dependent on whether we include more motives, as long as it is recognised that there may be other motives behind environmental innovations than environmental ones.

Such induction may work especially in sectors where there are relatively weak drivers to resource efficiency. What, then, about cases where there are stronger resource efficiency drivers? Can environmental motives add something to the brew then?

Clayton *et al*. further state that it is hard to distinguish cleaner technology from what is otherwise considered good process technology when resource efficiency is already strongly institutionalised as a motive for innovations (1999:241). This shows, again, that cleaner technology is a matter of whether the label of clean-ness gets attached to a technology or not in the process of innovation, rather than clean-ness being inherent in the technology.

However, Clayton *et al*. (1999:219) also state that environmental motives may reinforce the search for cleaner technology solutions (see diagram 3 in figure 2.1), unless hampered by occupational and organisational barriers between process engineering and environmental functions (*ibid*.:244), also in the case of strong resource efficiency drivers. But if there is little difference between resource-efficiency driven innovation and intentional cleaner technology, there seems to be little scope for environmental motives to add anything.

This discussion leaves us with the question:

- What is the scope for intentional cleaner technology, especially in the presence of strong drivers for resource efficiency?

To address this question, we need to know more about how environmental intentions interact with, and add something to, other intentions. We need to look in more detail at the articulation of different motives in the innovation process, and how they are made to bear upon the technological choices made.

In a sense this discussion is about the boundary between environmental innovation and other innovations, and as we have seen above it might for example be difficult to tell what is cleaner technology and what is not. An important aspect of this research project is to explore this boundary, and to seek to clarify the concepts of ‘environmental innovation’ and ‘cleaner technology’. Another question follows from this discussion.

- Is ‘cleaner technology’ a useful analytical concept? Or is ‘intentional cleaner innovation’ perhaps a more useful concept?

We shall return to, and refine, the questions raised here at the end of this chapter.

2.2 Problems regarding environmental innovation and the firm

We have in this chapter discussed the role of different motives – including regulatory pressure and resource efficiency – for environmental improvement in innovation processes. We have also addressed the concept of ‘cleaner technology’ and further problematised the relationship between intentions and environmental/technological outcomes.

For the discussion of cleaner technology we drew extensively on the interdisciplinary study by Clayton *et al*. (1999). The wider literature on environmental innovations includes contributions from many fields including economics and politics, but is dominated by management and business studies (what could broadly be labelled ‘environmental management’).

As mentioned above, an aim of this study is to engage with the environmental management literature and bring Science and Technology Studies (STS) to bear upon it. This disciplinary distinction matters in at least two ways. Firstly, and most obviously, STS can contribute a richer understanding of what technology is, and of the relationship between technology and organisation. The environmental management literature sometimes operates with too simplistic a conceptualisation of these issues. (The same applies to some of the other literature in the area from the fields of economics and politics.) We saw examples of this in the previous section.

Secondly, STS as a field in the social sciences is based on an interpretivist epistemology as compared to environmental management, which is dominated by a more positivist outlook. The discussion to follow will reflect the difference between positivist and interpretivist epistemologies, and to a degree be a rehearsal of arguments about these that have been made many times before in the social sciences. STS also enables a politically critical commitment that is rather different from the managerial perspective[20] of much environmental management literature.

We have identified two common problems in the literature on environmental innovation that reflect these disciplinary differences. The first problem is that of environmental management determinism, that is, an assumption that firm environmental performance will necessarily get better in the future. The second problem is a view of the firm as a rational actor who is able to implement management intentions straightforwardly into action. In the following sections we shall discuss these problems in more detail.

2.2.1 Environmental management determinism

There are many studies of so-called 'best practice'[21] in the area of environmental innovations: case studies of companies having excelled in improving their environmental performance, often in ways that are also commercially successful. The cases are thus intentionally selected (for example by studying firms that have won prizes for their environmental initiatives, or who take part in high-profile government programmes) with a bias towards firms with comparatively good environmental performance, and towards commercially successful environmental innovations. Based on this data the authors often assume that these practices are indicative of general business practices in the near future (see for example Zwetsloot, 1995:64 and Handfield *et al*. 2001:189). We propose to call this assumption 'environmental management determinism'.

This intentional bias is, more or less explicitly, motivated by a wish to promote good environmental practice, and to show that – in line with Porter – environmental improvements can increase firm competitiveness. And whilst this may be a laudable

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[20] That is the assumptions that management alone manage firms, and that management is a narrowly rational activity. We shall discuss this more later.

[21] Alternatively, entire companies are presented as actors doing best practice. These companies are

intention, there is a problem in terms of generalising the business case of environmental innovations based on these asymmetrical studies.

The underlying assumption is that other, less ‘progressive’ practices will recede, although these other practices are not explicitly studied. The studies tend to focus on explicitly environmental firm practices, to study the firm through a ‘green lens’. Rarely do they look at the environmental initiatives in the context of other practices in the case firms, perhaps with worse environmental consequences. (In terms of the Porter debate, the win-win cases are not compared to or contextualised with win-lose cases.)

This intentional bias contributes to the notion that environmental innovations are an easily distinguishable, separate category of practices, and underplays any interdependence between environmental innovations and other, less environmentally beneficial practices and any grey zone between the two. Especially in the case of cleaner technology this is problematic. As we have discussed above it is not always easy to distinguish between cleaner technology innovations and other innovations. Studies of best practice innovations ignore this boundary problem, and thus reinforce the impression of cleaner technology as straightforwardly embodying environmental intentions. Environmental management determinism thus tends to lead to reification of cleaner technology.

Sometimes the environmental management determinist assumption is formalised into stage models of firms’ environmental work. A common terminology is to talk of firms as laggards, compliers and pro-active firms (Noci and Verganti 1999:5; Sroufe *et al*. 2000:271; Richards *et al*., 2004).[22] The basic distinction here is the way the firm behaves in terms of compliance with regulation: ignoring it, complying with it, or taking voluntary action ahead of or independently of regulation.

There is merit to these models in that they do distinguish between different behaviours among firms, and in a context of ever more stringent regulation it is likely that some (especially large) firms have moved away from the laggard stage to at least compliance. However, there may also be assumptions made about the business case

[22] The exact terminology varies, as does the number of stages, but the basic idea is the same.

of environmental initiatives, and that it is in every firm's best interests, always, to move up the scale of the models towards a pro-active position – not because new, stricter regulations may be expected, but because this is soon going to be the normal way to do business and to be competitive. This linear progression is contradicted by Vickers (2000), who has shown that firms may well 'regress' from pro-active activities to less pro-active ones.

Another problem is that firm practices may well encompass behaviours at several 'stages' simultaneously (Schaefer and Harvey 1998:116). Stage studies tend to give an aggregated picture of firm activities that smoothes out or erases differing and even contradicting practices. Evidence of 'good practice' may not be a reliable indicator of what else goes on in a company. Similarly firms may well be moving both up and down the model simultaneously, so statements about trends need to be treated with caution. Again, this highlights the need to study environmental innovations in the context of other activities in the firm, so as to avoid generalising from instances of win-win situations.

2.2.2 The rational, manageable firm

A problem with treating firms as wholes is that it easily leads to a view of firms as manageable and rational. Often data is collected from managers thought to represent the entire firm (see for example Pujari 2006).[23] But any actor is likely to exaggerate their rationality, and it is also in the self-interest of managers (and a part of their self-image) to believe that they are managing the organisation. And whilst this is of course not altogether wrong, it may lead to an overly rational and manageable view of organisational life. That is, when management has decided something that is then straightforwardly implemented. Outcomes are seen as direct, automatic results of the decisions made, and there is no organisational dynamic that might influence and re-shape the implementation of management decisions, or even produce other decisions.

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[23] We will return to the theme of the rational firm throughout the next section. There we will also give more examples to back up the claim that this is a common feature of the literature on environmental

This underestimates the complexities of organisational processes and the uncertainties this creates for anyone trying to manage them. Different actors in the firm will have their own agendas and try to influence the outcomes. For example, Clayton *et al*. (1999:250) have described a case where a decision to invest in end-of-pipe technology blocked cleaner technology solutions and thus hindered potentially larger economic (and perhaps environmental) gains. It was in this case an Environmental, Health and Safety (EHS) unit with competence in end-of-pipe technology that managed to control the investment, and this locked in the end-of-pipe solution.

This example highlights the fact that organisations may produce unintended (by management and sometimes perhaps by anyone) outcomes. Companies as a whole and the actors in them are characterised by their bounded rationality (Simon 1982). Furthermore, we see that environmental innovations need to be seen not only in their technological context, but also in an organisational context. That environmental motives interact with other motives, as mentioned previously, can now be seen to be also about the politics of actors in the firm with their different agendas. An important point to make here is that strategic level actors in the firm do not have a monopoly on intentions and decision-making. The interests and preferences of all the actors in the firm, that is not just high-level managers but also engineers, environmental staff and others, may influence the decision-making.

The problem discussed in this section goes back to a basic issue of how to conceptualise technology (or innovation defined as technological change in a commercial context). Technology involves more than simply artefacts. It is also the competence, skills and expertise that go into the development and use of artefacts, and it is the organisation of artefacts and skilled people together (MacKenzie and Wajcman 1999). Seen from this perspective it comes as no surprise that the organisational context matters for environmental innovation, and that management decisions may not be straightforwardly implemented.

We have now treated three problems of the literature on environmental innovations, namely the conflation of intentions and outcomes, environmental determinism and the rational firm. These three problems are based on two related questionable assumptions: that firms are monolithic, rational actors, and that environmental innovation is an easily distinguishable category of innovations where environmental intentions are built into technological outcomes.

In the treatment of these problems, we have learnt some important lessons. Firstly, environmental innovations need to be studied in the context of other, notably technological, practices and activities in the firm. Secondly, we need to distinguish between what are one-off contingencies and what are longer-lasting changes in the organisations. And, lastly, we should study the agendas of different actors in the firm as a background to understanding how environmental motives are shaped, and how they interact with other motives.

To better understand the impact of environmental motives we thus need to look closer at the organisational dynamic within firms. In the next section we shall look at literature that deals with organisational issues relating to environmental innovations.

2.3 Environmental innovation and firm organisation

The last approximately 15 years has seen the beginnings of a literature on environmental innovations and firm organisation. The literature covers different manufacturing industries, mainly in Europe and the US.[24]

The literature covers different aspects of innovation processes. Some contributions are focussed on R&D whereas others study implementation of technology. There is also a distinction to be made between contributions focussing on production process innovations and those dealing with product development.[25]

This literature is diverse in terms of disciplines and, especially, the theoretical approaches used. The main contributing disciplines are management and business

[24] In part perhaps a reflection of the delimitation of this review to literature in English, but probably mostly because this has been a concern mainly in affluent countries.

[25] This thesis is about process innovations, but some literature on product development has been included here, due to the scarcity of literature on process development, and in the hope that the results will carry over. It is however important to keep in mind the differences between the two areas, and the text specifies which is discussed.

studies, organisation studies and innovation studies – the latter broadly defined as including both evolutionary economics and the sociology of technology.[26] We shall return shortly to the issue of theoretical perspectives, although it is worth noticing that a concern with (organisational) learning is common in this literature. In terms of methodology the literature is almost exclusively based on case studies.

We shall now present the main findings from the existing literature on environmental innovation and firm organisation. Relating back to the previous section, we shall structure the discussion around four themes: the *actors* involved in the processes of environmental innovations, the *intentions* behind the processes, and the *practices* involved in the processes. Finally, we shall summarise the *structural aspects* of firm organisation.

2.3.1 Actors

The main actors studied in the literature on environmental innovation and firm organisation are environmental staff.[27] Some manufacturing firms today have managers responsible for environmental issues. Some also have dedicated units with staff working on environmental tasks and/or environmental staff integrated in other functions. The literature reveals that the Environmental function is often co-organised with the Health and Safety functions, and the units are then referred to as EHS (or SHE, or HSE…) units.

Groenewegen and Vergragt (1991) studied the role of EHS units in social networks in firms. They identified three separate networks: production, strategy and

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[26] This classification is by necessity somewhat arbitrary for several reasons. Firstly, the level of aggregation could be different. For example, management and business studies can be subdivided into several more specific disciplines, here including environmental management and technology management. Secondly, these disciplines overlap to some extent. For example, organisation studies is a broad label overlapping several of the other disciplines.

The main journal of the field is *Business Strategy and the Environment*, with contributions also in journals like *Technology Analysis and Strategic Management*, *International Journal of Operations and Production Management*, *IEEE Transactions on Engineering Management* and *Journal of Cleaner Production*.

[27] There is no established convention for what to call these employees. Options include: environmental experts, SHE staff etc. They will here be called 'environmental staff'.

innovation. The role of EHS units was most well established in the production networks, but they also found some evidence of these units acquiring roles in the policy and innovation networks, although the EHS units had as yet had little impact on R&D (*ibid*.:53).

There is no clear picture in the literature of how important environmental staff are in innovation processes. King (1995; 2000) stressed that the role of environmental staff was intended to be a buffer between the firm and external environmental demands (mainly from regulators), but also saw that they were sometimes nevertheless able to contribute substantively to process innovations as information providers through their knowledge of the waste streams produced (King 2000:236). In the area of product innovation Lenox *et al*. (1997; 2000) found that cross functional teams that included environmental staff could work well as long as environmental staff participation was not imposed on the design engineers. The environmental staff here provided "*information about environmental design techniques, costs and benefits"* (2000:92) and thus acted as gatekeepers (1997).

In contrast, Handfield *et al*. (2001:198-200) found that environmental staff had only a limited role, and that there was a large gap between design engineers and environmental staff in terms of how important they considered environmental motives should be in the design process. The engineers also tended to see environmental considerations as constraints rather than as opportunities to express their creativity. Clayton *et al*. (1999:251) also found that engineers and environmental staff do not always cooperate. And that in such cases the latter will tend to promote end-of-pipe solutions, whereas the engineers are more likely to promote cleaner technology based on their process technology expertise.

There is surprisingly little written about the role of engineers in environmental innovation work. As indicated above, Handfield *et al*. (2001) found that engineers involved in environmental product innovation were relatively resistant to environmental considerations. On the other hand, Clayton *et al*. (1999:237) found that for process engineers involved in process innovations resource efficiency was a well-established design criterion. This difference may reflect the difference between explicit environmental criteria, and criteria like resource efficiency which are traditionally motivated by economic concerns.

It is also worth noting the existence of so-called environmental engineers. This is, however, not a protected title like for example chemical engineer, and this group of employees may therefore include quite different people. Their role in environmental innovation work is not clear.

There is rather more research on the role of workers in environmental innovation. A common theme in this literature is participation: the issue of whether workers are included in environmental innovation processes or not, and how constructive a role they get when included. There is a basic tension here between on the one hand professionalisation and specialisation – the use of dedicated environmental staff – and on the other hand recognition of the useful knowledge workers possess of operations (Forman and Søgaard Jørgensen, 2001:87; Boiral, 2005:356). The established traditions of control and cooperation between workers and management in general seems to heavily influence whether workers can contribute in the area of environmental work (Kamp, 2000:89). It would seem that workers do not have a special role with regard to environmental issues, but that their participation in this area typically reflects their participation in decision-making in general.

There is also a literature on environmental champions, some of which touches on technological innovation issues. It has been shown that environmental champions with high environmental awareness, a strong position and good credibility may have an important role to play in environmental innovations (Vickers and Cordey-Hayes, 1999:87-88). Environmental champions are therefore likely to be found in management positions. Vickers and Cordey-Hayes warned, however, that environmental initiatives resting on single individuals are vulnerable, and advocated broader collective processes of promoting environmental improvements in innovation work.

An environmental champion, unlike the categories of actors above, is not found in a particular organisational unit, and is perhaps better thought of as a role than a distinct actor category. It is also worth noting that champions are champions in a particular context. The emergence of environmental champions should be seen as an outcome of social dynamics inside the firm, as much as the result of individual efforts or characteristics (Clayton *et al*. 1999:251).

2.3.2 Motives

We have discussed previously in this chapter that other motives than explicitly environmental ones may lead to environmental improvements, but that explicitly environmental motives also matter. The focus here will be on the latter.

External drivers are important to the formulation of motives behind the production of environmental innovations. Green *et al*. (1994:1051) showed, based on a survey of UK manufacturing firms, that regulatory compliance was the most important driver. Compliance was followed by expectations of increased market shares (for product innovations) and cost savings through resource efficiency measures (for process innovations). Of these, cost savings is in a sense an internal driver, though no doubt often motivated by competitive pressures on the market.

Green *et al*. (1994:1057), however, also criticised the idea that changes in a firm's context automatically result in a modified firm strategy.[28] They drew on the sociology of technology to emphasise that there is also a process of interpretation, where external factors are perceived and translated by firm management into action plans. This highlights the process of strategy formulation, as part of the management of environmental innovations.

Management and strategy making should not be seen as a purely cognitive activity though. Halme (2002), drawing on a learning perspective, studied the development of environmental management paradigms in two Finnish firms. She showed that, rather than intentions being formulated first and then implemented, intentions and action co-evolved (Halme 2002:1103). The formulation of management intentions evolves in part as a response to experiences from operations. The formulation of

[28] There's a distinction here to be made between 'intention' and 'strategy'. The way these terms are used here, 'strategy' refers to official plans of action, whereas 'intention' includes also more informal desires to see things done a certain way. 'Motives' and 'intentions' are here used interchangeably though.

environmental management intentions thus depends on the existing operations of the firm, and thus on the history of the firm.

Such strategy formulation takes place in the context of firm management and may link to other strategies and different actors in the firm. Groenewegen and Vergragt (1991:53) noted that environmental staff (as part of units for environmental, health and safety work) had started to get a role in firms' policy networks. Vickers and Cordey-Hayes (1999:82, 84) identified cases where the environmental innovation agenda was promoted by, for example, the quality or the marketing functions. Consequently, existing structures in terms of the groups and units in the firm with their (political) agendas[29] are important to the formulation of environmental motives behind innovations.

That environmental innovation strategies may be political issues and not just a consensual process was also demonstrated by Steward and Conway (1998). Drawing on discourse analysis and network mapping, they observed that environmental issues were expressed rather differently to different actors. They contrasted a '*repertoire of conviction*' in communication with environmentalist communities with a '*repertoire of accountability*' in communication with management (Steward and Conway 1998:498-499). Both repertoires were used when communicating with employees. This suggests that firm actors are skilled at using different ways of framing environmental strategies depending on whom they are talking to, and for what political purposes. Again, this highlights the different roles played by different actors within (and outside) the firm structure in the formulation of environmental motives.

Both Halme (2002) and Vickers and Cordey-Hayes (1999) drew on an organisational learning perspective, which has proved to be a useful approach to the study of motives behind environmental innovations. It has allowed these researchers to distinguish between motives and actions, as well as see that different actors in the firm may have an impact on strategy formulation, and thus to avoid a conceptualisation of the firm management process as performed by one, monolithic

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[29] We also need to distinguish between 'intention' and 'agenda'. 'Agenda(s)' highlights the multitude of more or less conflicting intentions different actors in the firm may have. It also, however, focuses on the political aspects of intentions, and – compared to 'intention' – would tend to ignore the less

management group. The management process is a multi-actor process. Groenewegen and Vergragt's study (1991) confirms this, and they were also able to map the actors' roles in social networks (inside and outside the firm). These results highlight a methodological problem when studying firms' environmental innovation strategies. Different actors may have different strategy preferences. Asking only one person from each firm about the management of environmental innovations is thus problematic.

A problem with the learning perspective, however, seems to be that it easily leads to assumptions about the lasting effects of observed actions. If actions and changes in the firm are conceptualised as learning it seems reasonable to expect the firm actors to have internalised these practices and to build future actions on such experiences. But, as Vickers (2000:266) has shown, firms may also 'unlearn' environmental innovation strategies. He saw a firm changing from a proactive strategy back to a more reactive one. Vickers (2000) studied worker participation in environmental innovation processes, and whilst also drawing on an organisational learning perspective, was more sensitive to issues of power and conflict. Unlearning is not just a matter of forgetting the lessons learnt, but may also be a result of shifting agendas within the firm. This result also shows that structural change does not necessarily follow from a single event of environmental innovation. Structures are more obdurate than that, and reversals are to be expected.

2.3.3 Practices

First we need to recall that environmental intentions are not necessary for environmental outcomes. This means that practices other than explicitly environmental ones may be conducive to environmental improvement. For example, we saw above that resource efficiency as an established goal and practice may result in cleaner technology.

However, Clayton *et al*. (1999:248) also found that firms did not necessarily discover the opportunities available to them, even in cases where this would have led to economic gains. These authors explained this by reference to the bounded rationality of firms. In such cases introducing an explicit environmental motive may make firm actors see things in new ways and discover opportunities that would otherwise go unnoticed.

A way to make environmental change permanent is, thus, to integrate environmental considerations into routines and established practices. Some authors have studied the greening of process development practices. A study by Groenewegen and Vergragt (1991:51) showed that some firms routinely made environmental assessments of their development projects. This was confirmed by Green *et al*. (1994:1054), and for the case of product development by Handfield (2001:198). According to Miles and Green (1994:19), greening of R&D takes the form of modifications to existing technological trajectories in a firm, by amending the assessment criteria used, rather than any wholesale change to new trajectories.

Groenewegen and Vergragt (1991:53) also showed that, in addition to the engineers, EHS units had some role to play in environmental innovation processes, although it was not clear exactly what role, or how important it was. Studying product development, Lenox and Ehrenfeld (1997, see also Lenox *et al*., 2000) showed that successful environmental product innovations built on corporate environmental experts being linked into product development teams. The environmental experts here provided (as mentioned above) 'information about environmental design techniques, costs and benefits' (2000:92) and thus acted as gatekeepers (1997:195).

Clayton *et al*. (1999:251) have also called for the combination of environmental and process engineering expertise, especially for cleaner technology innovations. On the other hand, they also highlighted a case where an engineering group found it in their interest to promote cleaner technology, more or less in conflict with the EHS staff, who were oriented more towards end-of-pipe solutions (*ibid*.:252). Collaboration and conflict may thus shape environmental innovation in complex ways.

The literature suggests that there are two main management practices related to the greening of R&D. The first is building cross-functional teams as discussed above. Such teams may also go some way to shape the informal networks in the firm, which will remain after the team's work is over. Again, Groenewegen and Vergragt's focus on networks in the firm is useful here.

The second main management practice is the adoption of tools – standardised working methods. These include for example LCA (Life Cycle Analysis) and DfE (Design for Environment) tools for product development, and waste audits for process development. These tools range in sophistication from basic checklists to complicated software tools.

Lenox *et al*. (2000:92) studied the use of such tools for product development, and they found that they rarely delivered on their promises. Handfield (2001:202) supports this conclusion. Reasons for this included that the tools were seen as either too simplistic to be of any practical use, or too difficult and time-consuming to use (Lenox *et al*. 2000:92). These views could conceivably also reflect a low motivation to take environmental considerations into account, and these studies may underestimate the usefulness of such tools. In contrast, Holm and Klemmensen (1994) described a case of the successful use of a waste audit procedure in a Danish firm.

An issue raised by several authors is the question of the continued use of these practices. That is, studies often focus on the introduction of new greener practices, and in some cases assume that they will continue to be used in the future. Blomquist and Sandström (2004), for example, raise this issue in relation to product development practices in two Swedish consumer goods manufacturers. They found many examples of the introduction of new practices, but little evidence of embedding (conceptualised as second-order learning).

This issue relates to the discussion above about studies theorising action as learning, and the dangers of making assumptions about lasting effects. This shows that we need to have a processual approach to the study of environmental innovations, that is to take the firm's history into account, and assess whether the observed behaviour is due to temporary contingencies or the result of more stable, structural features of the organisation and its context.

2.3.4 Structures

The concept of structure highlights durable aspects of firm organisation; things that do not – most of the time – change easily or rapidly. It thus brings to our attention the history of the organisation and the stable qualities of it. Organisational structures mediate the influence of the organisational history and shape current events.

The literature reviewed above reveals some structural features of the firm. For example, Miles and Green (1994:19) showed that the technological trajectories of firms[30] are typically modified by environmental criteria rather than abandoned for new greener technologies.

Relatedly, the division of labour and knowledge in the firm is also likely to change slowly. Established groups in the firm have their specific expertise and routines, and their own agendas for what should be done (Clayton *et al*. 1999:251). We saw above that different groups in the firm may be involved in the formulation and framing of environmental motives, and they are likely to have different priorities in this process.

It was also noted that that routinising environmental concerns into technological practices (Green *et al*. 1994:1054) may be a way of integrating environmental considerations, but also that there were indications that introducing new such practices may be easier than establishing them on a permanent basis. There appears to be structural constraints to the setting up of environmental practices.

To call these things (the division of labour and knowledge, technological trajectories, etc.) 'structural' is not to say that they can never change, but the problems observed in the literature of achieving lasting change – the unlearning of proactive environmental strategies, the weak embedding of practices, etc. – confirm that we need to be careful not to overplay the lasting effects of individual projects and

[30] Dosi (1982:148) defines 'technological trajectory' as the direction of advance within a 'technological paradigm', which, in turn, is an established way of thinking when researching and developing a technology. Paradigms and trajectories are not in Dosi's account localised to a specific organisation, but – like Miles and Green – we may speak also of 'local' paradigms and trajectories in particular firms.

events. We need to be able to distinguish between temporal contingencies and longer-lasting structural change.

The authors cited here (Miles and Green 1994; Green *et al*. 1994; Clayton *et al*. 1999) all draw on the theory of evolutionary economics to capture the stable, structural features of firm organisations. Apart from the notion of 'trajectory', the 'bounded rationality' of firms and actors in firms is also a useful antidote to theories implying automatic immediate responses to stimuli, and constant change. Clayton *et al*. (1999:248) further drew on this concept (see section 2.1.4) to explain why firms do not necessarily discover opportunities for, for example, resource efficiency improvements. We shall introduce some of the basics of evolutionary economics in more detail in chapter 3 (section 3.1.1.1). For now, we may note that it is a useful theory in terms of explaining structural features of firms.

2.3.5 Summing up

We have in this third part of the chapter seen that environmental staff have some role in innovation work, but it is not clear exactly what that role is. In the literature they are seen as either barriers between the firm and external actors with environmental demands, or as gatekeepers securing communication between external and internal actors. Even less is known about the role of engineers in environmental innovation work. On the one hand engineering practice is seen to include resource efficiency concerns, but on the other hand it is unclear how engineers relate to more explicitly environmental criteria.

Workers appear not to have a specific role in relation to environmental innovations, and their participation (or not) depends on the conditions of participation in general. It has been shown though, that workers may have useful knowledge that can be drawn upon. Environmental champions are those actors that promote environmental concerns, in the context of innovation or otherwise. Successful champions are often found in a management position, where they can wield more power. What is not clear is how anyone becomes an environmental champion.

External pressure – regulation, customer demand, etc. – are important drivers of environmental strategy. The formulation of environmental intentions happens in a process of interpretation of external demands, and is affected by the agendas of the different actors in the firm. We should not think of this process as just a cognitive one though. The formulation of environmental intentions also co-evolves with action.

Firm practices do not have to include explicit environmental considerations to produce environmental improvements. But, due to the bounded rationality of firms, environmental considerations may trigger the firm to discover new opportunities for improvement. Two main environmental practices are described in the literature: cross-functional teams including environmental staff, and the use of special tools like LCA or waste audits.

Environmental staff participation in innovation work may be effective, and more so if this participation is built on existing networks rather than imposed from above. It is not clear, however, that collaboration is always more effective than conflict in producing environmental outcomes. The literature shows that the tools used to include environmental considerations in innovation work may work, but that it may be difficult to routinise their use. Overall, it seems important to distinguish between one-off introduction of these practices and well-established routines.

Finally, important aspects of the organisational structure that may have an effect on environmental innovations are: technological trajectories, the division of expertise and established routines. Evolutionary economics has proven to be a useful theory in explaining such structural features and their importance for environmental innovation.

There are, however, important empirical gaps in the existing literature on environmental innovations and firm organisation. Firstly, the roles of the different actors are unclear. Little is known about the role of engineers. We know that environmental staff have a role, but not quite what it is and how important it is. Secondly, it is not clear quite how environmental motives fit in with other agendas in the firm, such as resource efficiency, health and safety or quality, as well as the more political aspects of the agendas of different groups in the firm with their varying interests. Thirdly, we need a better understanding of how environmental concerns come to be embedded (or not) in firm structures.

On a more theoretical level, there is a scarcity of studies taking a political approach to the topic of firm organisation and environmental innovation. Approaches based on a rational and consensual view of management and organisation dominate. Hence the lack of attention paid to the interests and agendas of the actors in the firm. It is also not clear what the role of conflict in the organisation is in terms of producing environmental improvements.

We also need to be able to distinguish between contingencies and structural factors behind environmental behaviour, so as to understand better the embedding (or not) of environmental concerns into firm structures. We shall in the next chapter introduce a process perspective to address this need. Relatedly, we need to pay attention to the structural context of the behaviour of the actors. For example, the discussion of environmental champions showed that it is important to contextualise environmental promotion.

2.4 Conclusion

We have in this chapter discussed the impact of environmental regulation on firms in terms of technological innovation, as well as the possibility of voluntary firm action. With reference to the Porter debate we identified that cleaner technologies are examples of proposed win-win solutions to economic and environmental problems.

Whilst resource efficiency is an important driver for cleaner technology, intentional efforts to improve environmental performance (ecological rationality) may also help firms discover win-win opportunities. There are still questions unanswered regarding what such intentional efforts can add when there are already strong resource efficiency drivers present, how such integrated strategies play out in the organisation, and even whether ‘cleaner technology’ is still a useful concept in this situation.

A problem in the literature on environmental innovations is that it tends to conflate intentions and outcomes (and even conflates processes and outcomes). Discussing this problem, we saw the need to contextualise environmental innovations in terms of other technological practices and activities in the firm.

Another problem in the literature is that it is often biased by environmental management determinist assumptions, based on stage models and studies of 'best practice'. This leads to overly optimistic predictions of constant improvement. In terms of methodology it is important not only to study and explain best practice, but also normal or bad practice. Moreover, it is important to be able to distinguish between one-off contingencies and longer-lasting change. There is a need to contextualise environmental innovations in terms of also their temporal contexts.

There is also a tendency to assume that firms are rational and manageable, which underplays the role of organisational dynamics and the interests and agendas of different actors in the firm. We should study the agendas of different actors in the firm as a background to understanding how environmental motives interact with other motives.

Regarding the literature on firm organisation and environmental innovation, we have seen that much of it treats the organisation as rational and consensual. Studies with a more explicit political approach have highlighted the multi-actor character of environmental innovation work, but there is still a lack of knowledge about the roles and interests of actors in the firm. In particular, there is little knowledge about the roles of engineers and environmental staff in the context of environmental innovation. What, for example, is the impact of collaboration versus conflict between these two groups on the production of environmental improvements?

To avoid the environmental determinism trap, we need to pay more attention to what are contingencies and what is longer-lasting structural change. We also need to examine the structural context of the behaviour of actors in the firm. Especially, more knowledge is needed about the structural impacts on decision-making: the process of agenda-setting and interactions between different motives in environmental innovation work.

An important aspect of the aim of this thesis is to study the organisational integration of environmental motives into innovation processes. To do this, one must disentangle motives from outcomes, and look at the organisational decision processes in between and how actors in the firm shape these decision processes. There may be actors involved in an innovation process who promote environmental improvement. To understand how the roles of these actors relate to the resulting technological solutions, we need to study them in the structured organisational context of the firm. We may now expand and revise the set of questions stated above (at the end of section 2.1.4.). In the context of innovation work:

- How do different actors – with their expertise, interests, etc. – in the firm contribute to the shaping of environmental motives, and what influence do they have over the decisions made?
- What limitations and opportunities do organisational structures create for intentional environmental improvement, in agenda-setting and decision-making?
- What is the impact on the technological outcomes of intentional environmental considerations, especially on core technologies and when there are other drivers leading to environmental improvement?
- Is ‘cleaner technology’ still a useful analytical concept, and a relevant target for environmental policy?

3 A political process approach to the organisation of environmental innovation

We saw in the last chapter that we need to study the integration of environmental intentions into decision-making in innovation processes, and that to do this we need to study the roles of different actors in the firm in innovation work and to situate their behaviour in the structured context of the firm organisation. Specifically, to understand how decisions are made and influenced by the interests and agendas of the different actors, we need a political approach to these organisational phenomena.

In the first section we shall introduce the basics of a political approach to organisational studies, and in the second section we shall elaborate and apply this perspective to the issue of integration of environmental intentions into innovation processes. Throughout this section we shall further specify the research questions of this thesis. The third and last section will bring the themes of the chapter together and present the analytical framework.

3.1 Decision-making and actors

This section will introduce a political perspective on organisations. The focus will be on decision-making,[31] and, subsequently, on how to conceptualise the actors in the firm. The literature used will be mainly studies with a political perspective on organisations (and with a focus on technological or organisational innovations).

3.1.1 Organisational politics

As we saw in the previous chapter, it is common in the literature on environmental innovation and firm organisation to assume that decision-making is a rational activity as opposed to subjective or political, and that decision-making is the prerogative of management rather than a distributed activity among the employees in the firm. This

[31] Including agenda-setting.

managerial approach is common in spite of a long-standing critique of these assumptions from literature that is more aware of the political nature of organisations (Burns and Stalker 1961, Pettigrew 1985).

It is useful to take as a starting point of this debate the theory (as well as ideals and practices) of scientific management. This theory was based on the – bureaucratic – idea of rational planning of production, with operations mapped and correct procedure prescribed in detail with the aim of centralising control and optimising efficiency (Morgan 1986:30). Efficient procedures are here to be implemented top-down with management making all decisions on how to operate and being in control of implementation (*ibid*.:30). In this model of organisation there is no room for employee participation in decision-making, nor in any other creative activity. There is also no recognition of any other interests of managers apart from contributing to efficient operations.

Burns and Stalker (1961) criticized this practice as not being suitable for organisations that need to change rapidly in response to external developments. They contrasted in their analysis the organisation of scientific management – the mechanistic organisation in their terms – with that of the organic organisation. Whereas in the mechanistic organisation everyone has clearly bounded tasks and communication is primarily vertical, in the organic organisation tasks are more fluidly defined and communication among individuals and groups can be direct rather than go via the organisational hierarchy. Burns and Stalker replaced (at least to some extent) top-down control via management fiat by a shared commitment to the purposes of the organisation, and claimed that an important task of management is to create such commitment.

Burns and Stalker (and subsequent writers in this tradition) are commonly referred to as contingency theorists (Morgan 1986:48), meaning that they prescribed different organisational designs for different contexts rather than one ideal for all situations.[32] They claimed that in a stable environment the mechanistic organisation worked well, but in a rapidly changing environment an organic structure was better suited. This

[32] And, analytically, compared different models of management.

was also reflected in their interest in studying the organisation of R&D as compared to production, where, arguably, R&D work is difficult to routinise and plan in the same detail as production work. In this sense their theory also mirrored the rise of R&D as an important industrial activity in the post-war period.

So far we have seen that Burns and Stalker contributed the idea that a relatively fluid organisation can be more efficient than a mechanistic one. They also brought to attention the role of organisational politics and conflict within the organisation. To them, the organisation can be conceptualised as a work organisation – consisting of a system of management and the activities carried out (1961:97) – as well as a political system and a status structure. They recognised the existence of political interest groups with different agendas. Political behaviour is here seen to have its roots in the management system (demands for resources and control of other people) as well as in the status system (promotion, rewards, etc.) (1961:144-5).

However, Burns and Stalker see politics as a disruptive element in an organisation, leading to inefficiency (1961:146), rather than as a productive mechanism (Hård 1993:408). Their perspective is still managerial, in the sense of being primarily concerned with efficiency as opposed to other possible aims, for example democratisation. Reduction of direct management control is, for them, only advisable when a context of rapid change demands a more flexible organisation. And political behaviour is something that must be understood, but preferably avoided or controlled.

Interestingly this view of politics chimes with management ideology. Burns and Stalker themselves note that self-interest is typically not openly admitted in the firm organisation (1961:144-5). Political motives are not seen as legitimate rationales for behaviour, and are downplayed in favour of more consensual organisational motives. In this sense Burns and Stalker's theory is uncritical and serves to preserve management privileges.

For a more critical treatment of the political aspect of organisations we can turn to Pettigrew (1985). He sets out a treatment of political behaviour that is similar to Burns and Stalker, in that it is caused by the division of work and by "*career, reward* *and status systems*" (Pettigrew 1985:42). However, he refines the analysis of decision-making, based on a more developed treatment of power in organisations.

Pettigrew pays more attention to the context of decision-making in several ways. Firstly, he distinguishes between a strategic level of change (and decision-making) and an operative level of change, where the former sets the constraints of the latter. The strategic level of decision-making amounts to setting the agenda, that is, defining which issues are up for discussion and which ones are not. Influence is here a question of who has access to such agenda-setting. Secondly, he draws on Lukes's (1974) third dimension of power: ideology, to discuss different actors' unequal influence on each other's understandings of reality. This is a cultural form of power, determining how issues are to be understood and what intentions and interests are legitimate. Pettigrew (1985:44) speaks of the 'management of meaning' to capture this form of power.[33]

The particular group Pettigrew is interested in is internal Organisational Development consultants. He studied their political strategies, including their efforts to change the interpretive schemes used to formulate strategy (Barley 1987:177). Pettigrew emphasises that he does not wish to take sides in the conflicts he studies, and aims to "*let the data speak for themselves through as many channels and contexts, and over as long a period of time as possible*" (1985:50). This pluralist commitment is somewhat compromised when he chooses to explain the survival of the organisational development groups facing difficulties. Ultimately, he is interested in their survival and success.

It is worth noting that Burns and Stalker (1961:119) do talk of culture in organisations, but in their treatment culture is an apolitical phenomenon that serves to give cohesion to the organisation (especially in organic organisations where coordination through managerial fiat is weaker). For Pettigrew, in contrast, culture is, as we have seen, a political phenomenon, through which power can be exercised.

[33] Pettigrew thus runs the risk of over-estimating the intentionality of this form of power, as set out by Lukes. Ideology and culture may not be easily shaped by intentional efforts on behalf of management.

Moreover, Pettigrew's treatment of decision-making and power is linked to his treatment of organisational dynamics. He sees change events (and decisions) as part of '*ongoing processes of continuity and change*' (1985:26), thus emphasising that change does not come out of the blue, but is preceded by an organisational process, and is shaped by organisational structures and actions. Pettigrew describes change as a courtship process between a group championing a new rationality and the strategic context, potentially leading up to a marriage (1985:440), and criticises studies taking a snapshot view of change, neglecting the history of change events.

Strategic context here refers to the context of the group championing a new rationality. Pettigrew stresses a multi-level perspective with an inner context and outer context, the latter including the societal structures in which the firm is located.

Pettigrew's approach is ambitious, including as it does the several levels of context, the temporal process dimension, and a complex model of organisations (including formal organisation, activities, cultural aspects, political aspects, etc.). And there is in the end perhaps a problem with such a rich framework in terms of what exactly explains what, and what precisely is to be explained. No very clear model of organisational change emerges, and the approach is perhaps better seen as an approach to research, rather than a crisp (or rigid) theory of organisations. It does, however, offer a comprehensive framework for understanding the political aspects of organisations, and represents an ambition worth aspiring to.

A political process approach to organisational decision-making would seem to be useful to the study of integration of environmental motives into innovation activities in firms. By contextualising the decisions made and adopting a process perspective we should be able to avoid the determinist traps of separating out environmental activities and focussing on best practice.

A large body of literature has drawn on Pettigrew's work (see for example Schaefer and Harvey 1998 and Kamp 2000 in the area of environmental aspects of organisations). This includes researchers explicitly labelling their approach political process research (this literature is usefully reviewed in McLoughlin and Badham

2005). We will not here aim to review all this literature, but will draw on it when appropriate in the remainder of this chapter.

3.1.1.1 The limits of rationality and politics

We will here address the limits of rationality and politics in organisations, and therefore their limitations as explanations for organisational dynamics. For this purpose we will draw on mainly evolutionary economics, and this will also entail some broader reflections on the compatibility of this theory with the political process perspective.

We have seen how Burns and Stalker criticised the mechanistic model of management from the standpoint of efficiency, claiming that a more fluid and decentralised organisation is better suited for dynamic contexts. Analytically, they abandoned rationalistic theories of organisation since they failed to acknowledge informal aspects of organisations. Neither would Pettigrew sign up to an analysis based on a rational model of management, but in his case the problem with that model is that it underestimates the importance of politics (as well as history). Pettigrew, then, highlights the centrality of subjective rationality as opposed to the alleged objective rationality of scientific management.

A further challenge to the rationality of management comes from evolutionary economics.[34] A basic theme here is how a company (or a group within a company) searches for and processes information about itself, and more importantly, about its environment.[35] Evolutionary economists stress that a company has limited capability to search for and process information (Nelson and Winter 1974:888) because actors within a company have 'a bounded rationality' (Simon 1982).[36]

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[34] As mentioned in chapter 2, management may not recognise potential 'win-win situations. See also chapter 2 for a summary of evolutionary economy accounts of environmental innovations and firm organisation.

[35] Here referring to context, rather than the natural environment.

[36] And that differences in such capabilities help explain differences in performance between companies.

Evolutionary economics rejects the notion of maximisation (or optimisation) from neoclassical economics, which presumes access to complete information, and instead suggests that firms 'satisfice' (Simon, cited in MacKenzie 1996:51). This is taken to mean that firms normally settle for what is good enough, rather than try to achieve the perfection inherent in notions of maximisation.

Furthermore, satisficing behaviour is based on following routines for information search and processing (as well as for operations), and these routines limit what information about the environment gets brought to attention and how it is evaluated. Unless this limited evaluation tells the company that it needs to change, it will continue to follow its established routines (MacKenzie 1996:51). Stability is thus explained either by the evaluated information failing to meet established criteria, or because information was not picked up by the search and thus remained unknown.

This mechanism for managed change is essentially imperfect. A consequence of this is that it may also be different in different companies.[37] This means that different companies have different routines, and embedded in them, different criteria for what information to search for and how to evaluate it.

Evolutionary economics is in some ways compatible with a political perspective. As MacKenzie points out (1996:51), since different groups in a company may follow different routines and apply different criteria, organisational politics is possible. We agree with evolutionary economics that the limited capabilities of companies for search and evaluation – and the ensuing lack of information and knowledge – is a cause of organisational stability. The political process approach then adds nuance to how companies evaluate information, in bringing firm actors' interests to the foreground of the analysis. Interests matter for how and why criteria are negotiated and applied, and for what routines and criteria are adopted in the first place.

There are, however, ways in which evolutionary economics is less compatible with the political process perspective. Evolutionary economics emphasises the tendency of firms to reproduce existing routines as long as they do not perceive sufficiently

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[37] Compare the perfect, effortless adaptation assumed by neoclassical economics, which does not allow individual variation as that would mean deviation from the optimal.

strong signals from their environment to change them. In comparison with neoclassical economics this makes for a more realistic model of organisational dynamics, where instead of assuming continuous adjustments to changing external circumstances, periods of relative stability are interspersed with episodes of more rapid change. Furthermore, in evolutionary economics the organisation interprets the environment and judges the need for change, instead of seeing adjustments as following mechanically from a changing environment.

This view, however, makes organisations essentially reactive and risks underplaying internal politics as a dynamic force in firms. There may well be internal causes of changing routines and criteria. Whilst the political perspective tends to foreground the interior of the organisation it has been able to recognise both internal and external sources of change.[38] Pettigrew talked of the match ('marriage', 1985:440) between the interests of inside groups and the changing context, as a way of conceptualising change as a coming together of internal and external processes.

And whilst for Pettigrew there is still a clear demarcation between inside and outside, recently writers in the political process tradition have paid more attention to the blurring of firm boundaries. See for example Hislop *et al*. (2000) and Swan and Scarbrough (2005) writing on the politics of networked innovation.

We may draw out a further implication of evolutionary economics for our political approach. The political perspective of organisations is also based on a notion of rationality, albeit a more explicitly subjective one. By analogy with evolutionary economics we may also assume that political, explicitly subjective rationality is limited. Organisational actors will not evaluate everything, all the time.[39] There will be issues that are accepted without question, that is, are apolitical. (Which does not mean that they could not be politicised, just that they have not been). There are thus limits also to political rationality, and to organisational politics.

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[38] See for example Koch (1997) and Clausen (1997) on the roles of suppliers and consultants.

[39] In a similar vein a friend I had used to talk of every person's limited supply of 'indignation calories' to describe the need to focus one's engagement and the impossibility of caring about everything that one could conceivably care about.

This is in contrast to, for example, Knights and Murray, writers in the political process tradition, who see politics as not only inescapable but "*the very stuff, the marrow of organisational process"* (1994:xiv). Their version of the political process theory puts actors' efforts to manage their identities at the centre of organisational dynamics. A climate of competition and insecurity here means that identities are seen as constantly threatened and rather fragile.

Whilst this works well for them with their focus on organisational change and on managers and IT-specialists, this perspective seems somewhat less useful for understanding stable aspects of organisations, and those organisational actors – workers say – who find themselves in situations offering less scope to influence their own roles. The imperative of identity management in this theorisation threatens to override other goals and intentions. Actors that experience fewer threats and/or career opportunities may be less absorbed in the shaping of their organisational identities. We contend that, whilst politics is undoubtedly a central feature of organisational life, there is a risk of over-politicising the analysis in a way that blinds oneself to uncontroversial[40] but important aspects of organisational activities.

The idea of limited politics is not new. Mintzberg (1973) has written about the limits of a political model for studying strategy- (and policy-) making. He contrasts three schools of thought in this area, and their three models of strategy making. In his terms the three modes are: entrepreneurial, adaptive and planning. Briefly put, the entrepreneurial mode is characterised by a strong, risk-taking leader, the adaptive mode by bargaining amongst the parties of a ruling coalition, and the planning mode by management using analytic planning techniques for the long-term perspective. The adaptive model here corresponds to what we would call a political perspective.

Mintzberg sees these modes as different ways of making strategy, which can be used alone or in combination by organisations, and that the adaptive (political) model is most likely to be found in established organisations in complex, dynamic contexts (1973:49).[41] However, this conclusion is based on a partial view of politics, namely politics as bargaining. One should not assume that something that is not surrounded

[40] We will in this thesis not investigate 'ideology' (Haugaard 2002:38) in the sense of Lukes's third dimension of power.

by overt politicking is necessarily apolitical.[42] We may therefore distinguish between overt and covert politics, and furthermore see covert politics as distinct from the genuinely apolitical.

Thus far we have discussed decision-making as a collective process. The remainder of this section will deal with how to conceptualise the actors in the firm in a way that is compatible with the political approach.

3.1.2 Actors

The political approach to organisations as outlined here draws our attention to the different actors in the organisation, and their different roles and behaviour. It also emphasises that all employees are political actors in the sense that they may have a role to play in decision-making, potentially even regarding strategic decisions. Furthermore, a processual perspective asks us to not to lose sight of the context of the actors, but to see them as both producers and products of that context (Pettigrew 1997:338).

In particular, a political approach highlights the interests of the actors. We will here look closer at the concept of interests, preliminarily defined as what actors want to see happen in the organisation to themselves and others.[43] Especially we will consider what factors shape the interests of the actors. For the purpose of studying innovation processes, we will also introduce expertise as an important characteristic of organisational actors.

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[41] It is, however, unclear on what grounds these three perspectives are compared, and to what degree they are distinct phenomena, rather than the products of different theorisations. We would claim, for example, that there is no reason a priori to believe that planning or entrepreneurial leadership is apolitical. (For examples of the politicisation of planning see Brunsson 1989). Mintzberg has undoubtedly a point, though, that degrees of overt politicking vary between contexts.

[42] Firstly, if power relations are too asymmetrical, the weaker part may chose not to voice any concerns. Secondly, and more importantly when explaining the outcomes of decision-making, compromises between actors with different interests may be preserved without overt politics. For example, Kamp (2000:77) has described organisational structures as stiffened politics, where actors prefer sticking with a compromise to open conflict.

Interestingly this is compatible with evolutionary economics. For example, Nelson and Winter (1982, cited in Becker *et al*. 2005:781) have described routines as truces.

[43] We shall in this thesis focus on subjective rather than objective ‘real interests’ (Lukes 1974:25). This will suffice for the purposes of this thesis.

3.1.2.1 Interests

Burns and Stalker mention formal organisational position as a source of interests (1961:11), and note that a task (as defined by position) can be everyone's concern or just the concern of the person/group whose task it is (1961:69). In an organic organisation tasks are less clearly delimited, and there is a stronger commitment to the overall purpose of the organisation, whereas in a mechanistic organisation people's interests are less focussed on the whole organisation and more strictly limited to their own tasks.

In the preface of their 1961 book Burns and Stalker also mention employees' careers and their commitments to any political interest groups they are part of as sources of interests. Potential sources of conflicts between groups include competition for resources, money and control over others (*ibid*.:144-5). The authors thus recognise interests stemming from the formal (mechanistic) organisation, the culture of the organisation and, finally, the political system of the organisation. Given their view of politics as disruptive Burns and Stalker effectively make a distinction between the 'political' self-interests of individuals and groups and their 'productive' interests stemming from position/task and company commitment ('duty and loyalty').

Pettigrew in contrast see politics as a potentially productive force, and does not make this distinction between political and other interests. In this perspective it makes little sense to denote certain political interest groups, and Pettigrew instead emphasises the different rationalities of all groups. In 'rationality' he included problem-solving styles and time-orientations, but also goals and values (1985:42). Rationality is here, then, a political concept.

An underlying theme here is the identity of the individuals in the organisation, and how this identity is shaped and managed. As we have seen, Burns and Stalker see commitment to – that is, identification with – the company as a factor shaping the individuals' interests. We have also seen how membership of (smaller) groups matters. And, on an even smaller scale, the individual identifies with his or her task and position (both current and in the future, the latter aspect giving rise to career interests). Morgan (1997:161) adds private life commitments to the equation,[44] and claims that people will strive towards a fit between their private lives and their professional roles.

This point also highlights that interests are not only shaped by things internal to the organisation. Individuals' identities and interests span the organisational boundary. A further boundary-spanning mechanism is the group rationalities discussed by Pettigrew. Some group identities, for example membership of professions, will also transgress organisational boundaries.

Furthermore, we should be careful not to assume that actors' interests can easily be read off their positions, group memberships, etc. What is in an actor's interest also depends on how he or she interprets his or her situation. And whilst maintaining that an individual's situation and interests are in part shaped by organisational structures, the individual also has an active role in understanding and assessing the situation (and some influence on what situation to end up in).[45]

3.1.2.2 Expertise

In the context of innovation, the skills and knowledge of employees are of central importance. In a political approach such as the one developed here, it is useful to think of this in terms of the expertise employees have. This emphasises that possession of expertise in an organisational context is a matter of legitimacy. In other words, expertise is about who is seen to possess the legitimate knowledge or skills to solve a certain problem, rather than knowledge or skills as an innate property of individuals or groups. Indeed, Fincham *et al*. suggest that expertise should be defined as '*the capability for authoritatively applying special knowledge or skill*' (1994:19). The concept of expertise, then, highlights the interests of employees in maintaining or raising the legitimacy of their knowledge, by being seen to ably solve problems.

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[44] Although Burns and Stalker make a related point (1961:99).

[45] As stated above, we shall here limit the analysis to subjective interests, but even when including objective aspects of interests, the task of relating interests to positions etc. is not an easy one; individuals are located in the intersection of multiple social structures.

The status of a group of experts, and hence the legitimacy of their expertise, is determined by several factors. Not least among these is, of course, the status and position awarded by firm management, but Fincham *et al*. (1994:20) also suggest that the experts' positions in labour markets and professional accreditation can provide them with leverage in any power plays that occur in the firm. Indeed Fleck (1998a:145) emphasised the importance of (internal and external) labour markets in determining the legitimacy of expertise, by including it in his 'trialectic of expertise', a model of expertise with three dimensions: knowledge, power and tradability.

Expertise and interests are of course not independent phenomena. Firstly, it is worth noticing that trading expertise on labour markets relates to the career interests discussed above. Secondly, we again encounter professions as a link between employees' interests and structures external to the organisation. Burns and Stalker (1961:190) note that membership of professions is a source of status within the organisation.

More could be said about expertise – and about interests – but this will suffice to lay a foundation. We shall return to these topics in the next section.

3.2 The integration of environmental motives

In this section we will elaborate on some aspects of the political approach to organisations, and apply this perspective to our research aim of studying integration of environmental intentions into innovation processes. Before doing that, we need to introduce the innovation process, focussing on the firm level, and its environmental aspects. Again, we start with a rationalistic model and then progress towards a more politically sensitised approach.

The following two sub-sections are structured around the action-structure duality, and will deal with these two aspects of the integration of environmental intentions into innovation processes. We will first discuss the promotion (championing) of environmental concerns and thereafter the organisational structures that enable and constrain environmental action. Through this section we will, based on the theory set out, present the research questions of this thesis.

3.2.1 Innovations

The basic notion of technological innovation is the new application of technology to practical ends. The innovation process, then, is the activities leading up to and including the adoption of technology by users (Kline 1985:37).[46]

Often the focus in innovation studies is on the development of (or even research on) technology, rather than use, but researchers have shown that technologies are not fixed and stable as they move from development to use, but may be re-configured, re-interpreted etc. by users (Fleck 1998b; Lie and Sørensen 1996:10). The innovation process is a messy one, with typically many actors involved and numerous feedbacks, overlaps and contingencies (Williams 1997:173-4), and one should be careful not to assume that development and adoption are necessarily separate activities.

This thesis is primarily concerned with activities inside firms, and will investigate this part of the larger innovation process. Specifically, we will study innovations in production technologies in process industry firms. Such firms may or may not have internal development capacities, and the main focus is on technology adoption by firms, that is, firms as users of technology.

The focus on technology adoption – although as described above adoption and development are not necessarily distinct activities – leads us to consider the organisational aspects of technology adoption. Adoption of technology means that the new technology needs to be made to fit with existing technologies, as well as

[46] A few qualifications. Firstly, one may speak also of innovations in the public sector, which is not commercial, but traditionally the concept has referred mainly to industry. Secondly, new may refer either to what is novel to an individual firm, or what is new to the entire market. Thirdly, one may also speak of other innovations than technological ones, for example organisational innovations (Boer and During 2001: 83-4).

And from an environmental point of view it would make sense to include what happens to a product after its use, that is how it is reinterpreted and modified during recycling, waste treatment etc. – perhaps especially in cases of reuse, where the innovation process in a sense becomes circular.

existing organisational arrangements. Or, rather, that technology adoption is about constructing such a fit. And if we see a technology as a configuration of artefacts, routines, expertise, meanings, etc. (Fleck 2000:252), constructing this fit is about creating a new match between new and old artefacts, routines, expertise and so on.

Having thus set out the basic context of process innovation and firm organisation, we will here elaborate on the innovation process and discuss how environmental motives might be integrated into it. As in section 1, we will begin by setting out a mechanistic, rational model of the innovation process, and progress towards a more political approach.

Any larger innovation effort in a firm is likely to be managed as a project, with associated goals and plans, deadlines and other project management techniques to structure decision-making and work. In terms of decision-making (and work), this model suggests that the scope of decisions and the level of technological aggregation change through the process. They would change from the whole investment at the idea stage, down to a much more detailed level during the design and later stages (and back up to whole-project level at for example special decision points at the end of each stage). This corresponds to a division of labour between managers dealing with the overall picture, and employees solving more detailed problems drawing on their more specialised expertise.

In the project model there is also a progression from early stages, through a middle phase to late stages (a pre-determined project lifecycle, Hodgson 2004:86). In the case of investments in process technology this means something like: ideas and planning, design and implementation, optimisation and use. Moreover, the stages and levels intersect so that in early stages decisions are made at a high level of aggregation, and in later stages increasingly detailed decisions are made. As a consequence, employees can be expected to be involved less than managers in the early stages. Decisions at the whole-project level thus set the agenda by putting limitations on subsequent detailed decisions. Indeed, early decisions may decide what are considered major issues, and what are considered mere details.

Reality is prone to be much messier than this simple model suggests, in terms of feedbacks and concurrent activities (Williams 1997:173-4). It is also a highly rationalised and managerial view of the innovation process, neglecting the political aspects of what is going on. Nevertheless, the model is still useful to give an overview of the innovation process, and as a starting point for discussion of what a more political model would look like.

We may now also ask what integration of environmental motives into the innovation process might mean. The rational model described above draws our attention to the management techniques (project management, environmental management, technology management, etc.) used, and the different stages and levels of decision-making in the innovation process.

We saw in the previous chapter that certain project practices were important ways to integrate environmental concerns into innovation processes. Firstly, environmental criteria may be routinely used for project assessment (Foster and Green 2000:296, Handfield *et al*. 2001:198). Secondly, there is the application of environmental tools like life cycle analysis, waste audits etc. (Lenox *et al*. 2000:91). Thirdly, there is the use of cross-functional teams including environmental staff (Lenox and Ehrenfeld 1997:190, Lenox *et al*. 2000:91).

These practices and techniques fit neatly into the rational, managerial view of the innovation processes, when described as neutral instruments ensuring the implementation of management intentions. A closer look at the methods used for environmental innovation shows that they are far from mechanistic and neutral. They involve subjective judgements and choices open for negotiation. Holm and Klemmensen (1994) described an eco-audit project with the aim of improving environmental performance in a Danish firm. The extensive auditing work undertaken involved, for example, prioritising what waste streams to analyse in depth. A scoring system was used, based on various national classification standards, but in the end *"pragmatic reasoning and subjective evaluation"* was also necessary (*ibid*.:19). This example shows that even using well-grounded, formalised methods, there is room for – and a necessity for – judgement and choice, which in turn opens up a space for organisational politics. When studying the use of such techniques, we thus become aware that they are neither necessarily neutral instruments, nor necessarily lead to the implementation of management intentions in any simple, mechanistic way.

Indeed, we may say that rather than organisational rationality being reflected in such management techniques, organisational rationality is constructed through the use of these techniques. For example, project management relies on *"careful planning and firm control of critical variables"* (Hodgson 2004:85), and through such efforts managers seek to reduce uncertainties and achieve discipline and predictability (*ibid*: 85). (But, as we saw exemplified above, the success of such efforts is always only partial).

Management techniques reduce uncertainty about how to act, but they are also based on a particular body of knowledge and thus prescribe a specific way of interpreting the world. In the case of the eco-audit mentioned above, national standards of classifying environmental effects and risks were mobilised (Holm and Klemmensen 1994:19). Such standards vary between countries and are the results of particular choices and priorities. This highlights that the management techniques embody specific values – although they are surely to some degree open to re-interpretation – and may be more compatible with the expertise of some firm actors than that of others.

A political approach would question why certain practices and techniques are established and what interests they may serve. The criteria and tools applied are likely to reflect some actors' interests over others', both in terms of management control and in terms of competition between different groups of experts.

In a political approach the integration of environmental concerns is not just a matter of how, but also of who does the integrating and why they manage or not to do so. Looking back, again, to the literature review, we saw that the agendas of different departments or groups may influence the decisions made. In particular, the formulation of such strategy co-evolves with experiences from operations, rather than being a decoupled management activity (Halme 2002:1103).

We need to ask ourselves what determines who influences decisions and who promotes environmental concerns. As we saw above, managers may be more likely than employees to successfully do so. An important dimension of this is who has access, that is who gets to be a part of the project and who does not (see for example Remmen and Lorentzen 2000 regarding workers). The literature reviewed shows a core set of mainly managers and engineers, but that it is an empirical question if and to what extent environmental staff (and workers) are allowed to take part. Cross-functional teams including environmental staff may or may not be set up (Lenox *et al*. 2000:91).

This also relates to the notion of setting up an environmental function to buffer core activities from unwanted influences from environmental regulators (King 2000:224). Keeping environmental staff out may thus serve a function in letting the company manage different goals and external requirements in separate parts of the organisation, which may be helpful especially when those goals and requirements are seen to be contradictory (Brunsson 1989:11).

Mere access to a project does not, however, necessarily mean having a large influence. An important question is who is appointed to the more influential positions in the project, for example as project leader, and who has access to early stages of the process when important agenda-setting decisions are made.

As discussed in chapter 2, to understand environmental innovations in firms we need to look at the organisational aspects of the innovation process, and at how environmental and other motives are articulated and brought to bear upon the technological choices made, and how the technological and environmental outcomes are constructed in the process. We have here seen how this process is a complex one, in terms of practices and techniques, motives, actors etc. There is no straightforward connection between (some) firm actors' environmental motives and the environmental outcomes of innovation work. The impact of such motives will depend on who has access to decision-making, on what routines and practices are applied to the work, etc. Contingencies and uncertainties are likely to be as important as orderly, rational implementation of management strategies.

The first research question is therefore, as introduced in chapter 1:

1. *What is the impact of environmental intentions on the technological outcomes, especially on core technologies?*

We have here discussed the organisational aspects of technology adoption. A rational model of firm innovation based on stages, levels and project management techniques has been contrasted with a more critical political perspective. The political perspective opens up further questions regarding access and influence, as well as how project practices may reflect different actors' interests.

These issues of influence and power will be discussed in more detail below. Firstly we will focus on the – successful and unsuccessful – promotion of environmental concerns by individuals and groups, and thereafter we will shift the focus to the organisational structures that define opportunities and restraints of environmental promotion in the context of innovation processes in firms.

3.2.2 Environmental championing

The shaping of intentions and motives in innovation processes is done by the actors in the firm. Actors who have an interest in taking environmental aspects into consideration may promote those issues in the decision processes, and thus act as carriers of such environmental intentions.[47] This section will focus on environmental promotion, and conceptualise it in terms of action and structure. Thus, the different influence of actors will be seen as reflected in the success, or lack of success, of their environmental promotion.

A common category of actor in the literature on environmental management is the environmental champion (see, for example, Anderson and Bateman 2000). This is a parallel to the literature on innovation, where the innovation champion is a common

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[47] It is perhaps worth noticing here that an interest in promoting environmental issues does not pre-suppose heart-felt environmentalism on behalf of the actor. Such an interest may be rooted, as we shall see later, in other things, for example raised status or control of resources.

Moreover, this definition of promotion (championing) is not limited to large issues, initiatives, etc., but includes also smaller ones.

character (for a review see Jenssen and Jørgensen 2004), and to the change agent of organisational studies (Burns and Stalker 1961:199; Buchanan and Storey 1997). We will draw on these sets of literature as well, since although they highlight different actors with different skills, there is a common theme of conceptualising promotion (of the environment, of a technology, etc.).

There are different approaches to conceptualise what a champion is. At one end of the spectrum are models where the champion possesses certain qualities – like enthusiasm and willingness to take risks – which are what makes him/her a champion. This way of understanding champions risks underplaying the organisational context of the champion, and overplaying the achievements of the champion.

Another, but related, weakness with this model is that the champion tends to become a hero, and everyone who does not accept the ideas of the champion becomes a villain.[48] Resistance is in this model seen as destructive politicking, indeed politics is seen merely as something negative, rather than something a champion would be involved in to promote his/her aims. Whilst uncritically taking sides with the champion may serve well in an account with a highly prescriptive aim, analytically it runs the risk of neglecting the political dimension of environmental promotion, and to imbue champions with too narrow a range of motives.

A better way of understanding champions is to focus on the behaviour of championing (promoting) the environment. Anderson and Bateman (2000) studied the ways champions framed and presented environmental initiatives and compared successful championing attempts with unsuccessful ones. This approach recognises that the organisational context matters for championing, and that champions need to be reflexive about what they do. However, this is still a push rather than a pull model in its concern with the receptivity of managers to champions' ideas.

At the opposite end of the action-structure spectrum is a structural model of championing. Here the organisational context stimulates the emergence of champions by creating opportunities for employees to assume this role. The findings

[48] Tidd *et al*. (2001:327) even speak of 'assassins'.

by Fincham *et al*. (1994) illustrate this model. They studied the careers of IT specialists in financial sector firms, and observed how there were structurally defined opportunities for this group of employees to further their careers by championing IT in these firms (and thus also strengthening the legitimacy of their own expertise) (Fincham *et al*. 1994:276).[49]

This structural model thus highlights the organisational context of championing, but it also encompasses an action component in that potential champions must choose to take the opportunities offered to them by the organisation. The model thus avoids extreme structural determination.

Furthermore, the model of Fincham *et al.* (1994) is political, and career- and self-interest is here part of what motivates the champions. Heroic models of champions tend to be uncritical of the champion's goals (environmental improvement, technological innovation, organisational change, etc.), and describe them as benefiting the whole organisation. An explicit and perhaps extreme example of this is given by Jenssen and Jørgensen (2004:80): "*It seems that the champion always acts unselfishly and in the best interest of the organisation but the organisation and its leadership do not understand this and resist change*". A political approach may reveal a more complicated set of motivations and interests.

Attention to political factors is thus a useful way to counteract the heroism-tendency of much of the champion literature. Another way to achieve this is to look at what other roles are played by firm actors in organisational change. For example, Tushman and Nadler (1996:151-2) present four roles that are 'critical' to innovations: idea generator, internal entrepreneur (champion), boundary spanner (gatekeeper) and sponsor (mentor). Whilst such typologies are somewhat arbitrary

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[49] The study by Fincham e*t al*. also highlights that championing can be a collective effort – a notion that is often lacking in champion research (Jensen and Jørgensen 2004:65), although Anderson and Bateman (2000) also talk of alliance-building.

We may here refer back to Pettigrew (1985:481) who distinguished between different categories of alliances or groups promoting issues: hierarchical units, task forces, voluntary associations and networks. This categorisation also highlights the difference between groups with a mandate from management (the first two) and those that may need to operate without such legitimacy (the last two), which again draws our attention to the opportunities offered or not by the organisational structure.

this set of roles serves to emphasise that champions are but one of the roles necessary for change,[50] and so it puts the contribution of the champion into perspective.[51]

A further relativisation of the champion comes from Buchanan and Storey (1997) writing about organisational change agents. They point out that individuals may change roles during a process of change (and by analogy an innovation process), and point to role-taking and role-switching as important aspects of championing. This highlights the process of becoming (as well as ceasing to be) a champion, which is in conflict with essentialist and therefore static theorisations. And whilst Buchanan and Storey's perspective is strongly actor-centred, we would argue that there is also a structural, contextual component to the process of becoming a champion.

In relation to environmental innovations environmental staff would seem to be natural candidates for the champion role, given their (presumed) knowledge about environmental aspects, at least when they are given access through inclusion in project teams. As we have seen, King showed that environmental staff are sometimes able to be gatekeepers between the environmental and engineering functions in the firm (1995:276; 2000:236). On the other hand, managers may be better situated to successfully promote environmental issues (Vickers and Cordey-Hayes 1999:87), but it is less obvious that they would recognise a need for doing so. It remains to be seen if the organisation offers any opportunities for promoting the environment in the context of innovation processes, and if so, who will take on this role.

We have here discussed and criticized the common individualist (essentialist) models of environmental champions. The hero-like qualities of the champion have been relativised by focussing on championing as a behaviour rather than as a trait, and by looking at broader sets of roles played in change events. Accounts of championing with a more political slant highlight self-interest among the motivations in choosing to take on the champion role. Structural models draw our attention to the importance

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[50] Buchanan and Storey call this approach to management research 'listology', and argue that the point of such lists is the plurality of roles they point to, rather than any particular set of roles they portray (1997:140).

[51] It is also a rather functionalist model, but nevertheless we may employ it to relativise champions.

of the organisational context in producing opportunities for championing. This leads us to the second research question, as introduced in chapter 1:

2. *How do any environmental concerns that firm actors may have affect the decisions made in innovation processes?*

In the next section we will further discuss the organisational structures that form the context of environmental championing.

3.2.3 The social constitution

In this section we will focus on the structural aspects of organisations that shape decision-making and any efforts to promote environmental issues. We will draw mainly on the political process literature for this, and in particular the concept of the 'company social constitution' as introduced by German and Danish scholars in this tradition. We will discuss how the social constitution allows for, hinders or shapes the integration of environmental motives into innovation processes.

Structures are relatively durable features of an organisation, but they are not static. To avoid such a conceptualisation we will also pay attention to mechanisms of structural change and how environmental concerns may come to be embedded in the structures of the organisation. The issue of integration of environmental concerns here becomes an issue of embedding as integration that lasts, and of shifting the organisational limits to such integration.

The concept of the 'social constitution' of a company was introduced by the German scholars Hildebrandt and Seltz in 1989 to describe existing compromises among actors in the organisation, primarily between employees and management (cited[52] in Kamp 2000:77). The social constitution is said to develop over time and come to constitute a system of implicit norms and values, or 'stiffened politic' (Kamp 2000:77). Clausen describes it as the *"concerted norms, rules and principles in the company which influence employees' behaviour, motivation and attitude*" (1997:174). Among the policy topics central to the social constitution we

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[52] Their publication is in German and therefore I have not read the original work.

find work content and responsibility, control of work performance, careers, etc. (Koch 1997:138).

The company social constitution pre-supposes the existence of conflicts of interest. Although it has mainly been used to study employer-employee conflicts, Clausen points out that it can also encompass a variety of lines of conflict and not just two opponents (1997:174). And, whilst inspired by a Marxist tradition, it focuses on actors' own understandings of problems rather than any objective interests (Clausen 1997:174).

The assumption of conflicts of interest does not mean that the concept of the company social constitution mainly explains overt conflict. On the contrary, it serves to explain also the normal, stable situation of compromise and, in this sense, consensus. Kamp expresses this (with reference to Pettigrew) as political processes that serve to stabilise and reproduce the existing order (2000:76).

This does not mean that the company social constitution is static. It can break down, and does so sometimes. Furthermore, the relative permanence of the social constitution, that is, its reproduction as a social structure, is not automatic but requires effort. Once a compromise is in place, the actors have an interest in maintaining it or pay the price of overt conflict. When acting within the existing compromise, the actors in the firm take the established interests of the other actors into account. They often 'reflect' the interests of the other actors, rather than negotiate them explicitly (Kamp 2000:77).

Such reflection may happen, to a degree, unconsciously as the actors internalise the terms of the compromise. We here see a link to the cultural aspects of politics, as described by Pettigrew, and Kamp stresses that the social constitution concept refers to actors' own understandings of structures, rather than structures in an objective sense (2000:78). This fits well with Clausen insisting, as we saw above, on the concept focussing on the actors' own understandings of their problems and interests.

The term 'compromise' does not imply an even distribution of power, just that opposing actors' interests can not entirely be ignored, given the potential disruptiveness of open conflict. However, this assumes that no actors can be ignored. This may be a reasonable assumption when studying employer-employee conflicts, at least in unionised workplaces, but perhaps less so for other actor categories and other lines of conflict. We need to be aware that the prevalent rules and norms may disregard the interests of some actors.

Although the concept of the social constitution of companies primarily refers to how people relate to each other in the organisation, several writers have stated that the social constitution is also a lens through which organisational actors interpret the external context of the organisation. Kamp refers to the social constitution as a lens (2000:77), and Remmen and Lorentzen as a filter (2000:366). The existing compromises set out the agreed positions on different issues, and come to shape how the actors interpret what goes on both in and outside the company.

3.2.3.1 Innovation, expertise and the social constitution

The social constitution concept does not explicitly refer to either innovation or environmental work, although it has been applied to such topics,[53] – for example, to the adoption of IT solutions for managing production (Clausen 1997). It has also been applied in the area of environmental work by Kamp (2000) studying the introduction of environmental (and health and safety) management concepts, and Remmen and Lorentzen (2000) who studied worker participation in cleaner technology projects.

For example, Remmen and Lorentzen showed that there was an emerging consensus between trade unions and employers regarding the importance of environmental work (2000:370), but that in some companies with weak traditions of worker participation in decision-making environmental work was managed in a way that invalidated the experience and expertise of the workers (2000:368). Kamp similarly

[53] It may therefore be useful to compare the concept with similar concepts that are more explicitly about technology. A related concept is that of a technological regime. A regime is a "*multi-layered set of rules and grammar operating in and derived from the complex of 'scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up technology'* " (Russell and Williams 2002:118, citing Geels and Schot 1998).

This concept shares a focus on rules and norms with the notion of the social constitution, but there are several differences. Firstly, the locus of these rules and norms is a technology in the case of the regime, and an organisation in the case of a social constitution. Secondly, the regime concept is concerned with the different social dimensions of technology, but the social constitution concept is more explicitly political in that it deals with interests and conflicts.

showed how in the introduction of an integrated health, safety and environmental system, the new environmental management practices were influenced by traditions of participation in health and safety (2000:88).

Existing applications of the 'company social constitution' concept have thus focussed on conflicting interests between workers and employers. In this study the focus is more on highly educated, white-collar employees than on workers, and the concept therefore needs some modification. This will be done through a discussion of 'expertise'. We will here first set out some issues regarding expertise in environmental innovation work, and thereafter discuss how these issues may be understood through the concept of the social constitution.

Expertise in firms is often compartmentalised into formal organisational units, or into occupational categories (Fincham *et al*., 1994:20-21). For example, environmental expertise may be found within environmental, health and safety units or with environmental engineers positioned in other parts of the organisation. The divisions of expertise, that is the boundaries between organisational units or between occupational categories, is part of what is contestable between different interest groups in firms.

Expertise is a resource for a group of experts in their efforts to gain influence in a firm, as well as an outcome of such efforts. Thus, with reference to environmental innovations, it is suggested that important issues may be conflicts regarding the boundaries between areas of environmental and technological expertise, and that the legitimacy of environmental expertise may be questioned.

In the context of environmental innovations, Clayton *et al*. (1999:251) for example (as mentioned above) found cases where environmental staff sought to limit the solutions to environmental problems to end-of-pipe technologies since that was the kind of expertise they possessed. It was in their interest to promote such solutions, as this legitimised their expertise.

Whilst beneficial for the development of specialist knowledge, the division of expertise also gives rise to coordination problems, as well as communication problems between groups of experts. One proposed solution to this is the development of hybrid expertise, that is, staff with some knowledge in both fields of expertise (Fincham *et al*. 1994:22) that facilitates cooperation and communication. In relation to environmental innovation, the role of environmental engineers as potential holders of hybrid expertise is especially interesting.

In terms of the social constitution, boundary disputes are examples of horizontal conflicts between competing groups of experts[54]. Examples of potential conflict topics in the context of innovation processes are the role of environmental design criteria and the relevance of environmental expertise for technological work.

But any such conflicts also take place in a hierarchical organisational context. Management is likely to want to have a say on matters of who does what and how it is to be done, that is, whose expertise is relevant for what tasks and what routines are to be followed. Management techniques like setting up cross-functional teams and supporting or mandating the use of environmental design tools can thus be seen to have political implications.

Indirectly, management will also influence the relative status of groups of experts through for example salaries and promotions. Management has a relatively large degree of control over the internal labour markets where expertise is valued, and over whose expertise is important and central to the organisation. This does not mean that management authority determines everything. Expertise may be difficult to evaluate (Fincham *et al*. 1994:241) and to manage, and there is room for manoeuvre for the employees as well. For the individual employee, striving for promotion is an obvious way of attempting to raise the status of his or her expertise (Heimer 1984).

As discussed previously there are limits to politics[55] as an explanation of behaviour in organisations. Environmental aspects may have remained unpoliticised, and the absence of environmental motives in innovation work should not automatically be taken to mean that they have been excluded. We would, however, argue that different actors in the organisation are likely to have, to some degree, different interests

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[54] As compared to previous work using this concept focussing mainly on conflicts of interest between blue-collar workers and management.

[55] In terms of decision-making and agenda-setting.

regarding the importance of improving environmental performance and regarding how to do it (Kamp 2000).

Expertise is thus formed, promoted and managed in a structured context of interlinked vertical and horizontal conflicts of interest. We are here extending the concept of the 'company social constitution' to encapsulate established norms regarding the boundaries of types of expertise, and the status and interaction between different experts. The social constitution will shape who has access to decision-making and work as part of the innovation process, and thus who will be in a position to promote environmental concerns.

The social constitution further highlights stiffened, covert conflict, and not just overt conflict. We would expect its norms and rules not to be constantly fought over, but often accepted, or even taken for granted, and reflected in the work practices and informal networks established. The social constitution thus shapes the ways in which environmental concerns may be integrated in work practices, and how environmentally committed actors may be included in influential informal networks.

Finally, the social constitution draws our attention to historical developments in the organisation, and how the current constitution has been formed and established over time. This will allow us to distinguish between one-off environmental improvements, and more long-lasting structural changes embedding environmental concerns into the organisational structures.

We have here introduced the notions of 'the company social constitution' and 'expertise' to theorise structural organisational limits to the integration and promotion of environmental concerns into innovation work. Our third, and last, research questions is, as introduced in chapter 1:

3. *What are the structurally determined organisational limits and opportunities to the integration of environmental concerns into firm innovation processes?*

3.3 Conclusion – the analytical framework

To sum up, we have seen that integration is here a matter of understanding the role of environmental concerns in the innovation process, and especially in decision-making. Environmental concerns will be brought into the process through environmental championing, that is, individuals or groups promoting environmental concerns. Such championing will be shaped by the social constitution of the firm. It may even be that the constitution changes over time, thus resulting in a more rooted, lasting integration of environmental concerns.

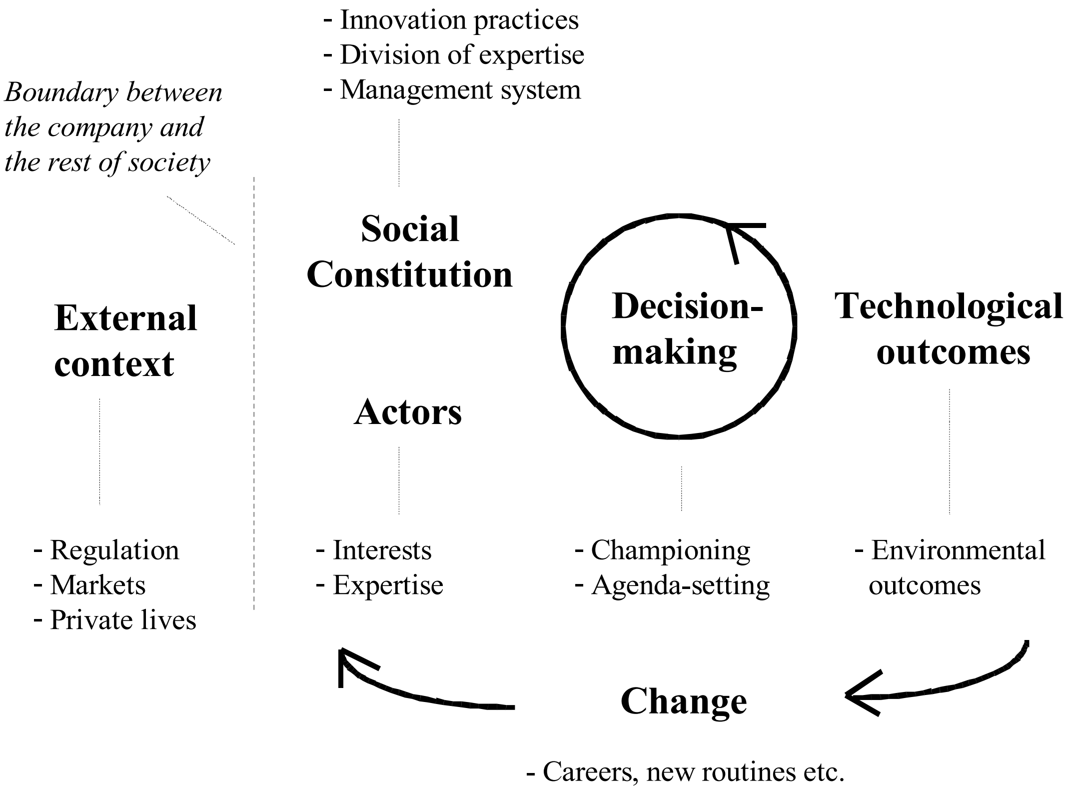
Figure 3.1 illustrates the main aspects of the resulting analytical framework. At the centre of the framework we have decision-making as part of the innovation process. Actors articulate and promote (champion) different objectives including, perhaps, environmental performance. Decisions about detailed solutions are made within the confines of an agenda largely set early on in the process.

These actors bring their interests to bear on their actions in the decision-making process, including career interests, concerns for the legitimacy of their expertise, etc. The actions and roles of the actors are enabled and restricted by the social constitution of the organisation, central parts of which are established routines and practices, the existing divisions of labour and expertise and the management system.

The actors and the constitution thus form an internal context for decision-making. Influences from the external to the company context include not least regulation and product market pressures, but also the individuals' private lives and their positions on external labour markets.

Finally, the framework encompasses the processual, temporal aspect of organisational life, where stability and change are the products of the actors' behaviour. Career moves and changed routines and practices are important examples of categories of change.

Figure 3.1 Analytical framework



This framework will help us answer the research questions set out in chapter 1, and avoid the problems of the environmental innovation literature identified in chapter 2. The framework avoids reification of environmental motives, by analysing them as distinct from the technological outcomes, and in the context of other motives. The processual focus will expose change both for better and for worse, and enable us to distinguish between one-off changes and rooted change, and thus help us avoid environmental management determinism. The attention to the interests of multiple actors will help towards a non-managerial[56] analysis. Furthermore, the framework will allow for an analysis that is sensitive to both structure and action aspects of decision-making. In the next chapter we will seek to develop a methodology through which this framework can be implemented.

[56] That is, one that recognises the importance of politics.

4 Methodology

In the literature review (chapter 2) we discussed some problems identified in the environmental management literature. Based on this discussion we identified the need for a contextualist, processual and political theoretical approach, and such an approach was elaborated in the previous chapter.

This chapter aims to present the methodology used in this research project, and to justify the research design choices made. The first section sets out the starting points of the research project and some of the main analytical choices made. Thereafter, we shall discuss the empirical part of the project, and, finally, issues relating to the analytical methods used in a separate, third section.

A few comments need to be made before we start. Firstly, research is an iterative process and the different parts: literature review, analysis, data collection, etc. to an extent progress in parallel, and are interrelated. It has been attempted to make such dynamics and connections explicit whilst writing a linear narrative about the methodology. Secondly, the choice has been made to not tack on issues regarding ethics and reflexivity in a separate section, but to integrate them where appropriate throughout the chapter.

4.1 Research strategy

4.1.1 Starting points

We shall here take the research questions (previously stated in chapters 1 and 3) as starting points for the development of a methodology for this thesis. The first research question is:

1. *What is the impact of environmental intentions on the technological outcomes, especially on core technologies?*

As discussed in chapter 2, we need to avoid conflating environmental intentions and environmental outcomes, and instead analyse them separately, especially in the case of cleaner technology. We therefore need to unpack the innovation process, and study how environmental intentions are articulated there and brought to bear upon the technological decisions made as part of this process. This is one of the reasons why we shall choose a case study approach, which will help us capture in some detail the processual character of innovations. See section 4.1.2.

Moreover, we have stated in chapter 1 that this research project is about exploring the boundary between environmental innovations and other innovations (especially between cleaner technology and other core process technology). This means that we need to avoid studying innovations through a 'green lens', that is to assume a separate set of environmental activities. Instead we need to contextualise the environmental aspects of the innovation process, to study environmental intentions in the context of other intentions, etc. This has consequences for what innovations to chose for study. Instead of studying only 'best practice' environmental innovations, we need to study a range of cases with varying environmental ambitions and outcomes. See section 4.2.2.

2. *How do any environmental concerns that firm actors may have affect the decisions made in innovation processes?*

This research question highlights the multiplicity of actors that may be involved in the innovation process, and the possibility of them promoting environmental concerns in this context. The question requires that we study the motivations and interests of the participants, which is best done by engaging with multiple informants for each case as opposed to choosing a single informant to speak on behalf of all the others (which, as we saw in chapter 2, may contribute to overly rational and managerial results). See section 4.2.3.

Question number 2 further enquires about the issue of how innovations are promoted, and how actors can bring influence to bear on this process. This supports the choice of a qualitative approach, which is better able to catch both the formal and informal aspects of organisational dynamics (Marshall and Rossman, 1989:46). See section 4.1.2.

3. *What are the structurally determined organisational limits and opportunities to the integration of environmental concerns into firm innovation processes?*

This research question further highlights the structural aspects of the organisational context, seen as a dynamic aspect of the organisation that changes over time. This is an analytical category capturing on the one hand the organisational obstacles that limit any actor's influence, and on the other the opportunities the organisation provides to the actor enabling action. Structures thus need to be evaluated and understood from the viewpoint of a particular (individual or collective) actor. What is structural and unyielding for one actor may be amenable to change by the actions of another.

The main methodological implication of this research question is about what data we need. Firstly, we need data about the organisational context[57] of the actors' behaviour, that is, how they understood the context of their action. Secondly, we need data about the history of that context. The interview themes following form this research question, as well as from the previous two, will be discussed in more detail in section 4.2.4.

4.1.2 Case studies and unit of analysis

This research is – at the most general level – about making peoples' everyday experiences accessible to academic reflection, about providing concepts and categorisations that reflect people's lives, but that also form a systematic framework capable of generalisation. The wish to gain access to people's own understandings of their situation and to analyse this within a complex setting calls for a qualitative approach capable of dealing with the required richness and complexity of data, as well as the situatedness of the object of study (Marshall and Rossman 1989:46).

[57] 'Organisational context' here refers primarily to the internal organisational context, but also to the external context – for example regulation – as it impacts on the organisation and shapes the internal context.

There is a strong tradition of case study research in STS, and for good reasons. Firstly, to understand the co-evolution of society and technology (or science), we need to study technology (and science) in a social context. It is important to note here that social context is not only society at a macro level, but also the social aspects of the micro setting[58], in this case organisational roles, routines etc. Case studies are a good strategy for studying objects in their "*real-life context*" (Yin 1994:13). A richer picture can be painted than using, for example, surveys. Secondly, and relatedly, case studies are good for dealing with complex topics where there are many dimensions (more variables than data points, Yin 1994:13).

This study deals with many levels and objects of analysis: nations, industrial sectors, firm organisations, people, decisions etc. The empirical core of the study, however, are the choices (decisions) made as part of investment projects. Such choices are what links (or not) intentions and outcomes, and they are influenced by the actors and structures of the particular organisation, which in turn are influenced by sectoral and national circumstances. The unit of analysis is therefore the technological choices made relating to an investment project.

Four investment projects in four firms will be studied and written up as four case studies. There is a sense, however, in which we have more than four cases. It will also be possible to compare individual decisions in the same project.

4.1.3 Comparative analysis

It was judged that it would be possible to make several case studies within the limitations of the research project. This would have the benefit of enabling comparative analysis. Multiple cases can improve the precision, validity and stability of findings (Miles and Huberman 1994:29).

Each case study was pursued until the major technological choices of the project were identified and explored, and until respondents representing the different categories of actors identified in the literature had been included.

[58] And to try to reconcile the macro and micro level settings (Russell and Williams 2002:61).

More detail could have been elicited with a participant observation method. It was judged, however, that interviews would yield enough detail to understand the technological choices. Using a participant observation method would also have consumed more time per case study, thus reducing the scope for comparison of cases.

This comparative approach raises the issue of what comparison is and how it can be used to yield useful results. It is essentially a game of similarities and differences between cases. Cases are selected that are at the same time similar in some respects and different in others. Similarity enhances comparability, and differences in one dimension can shed light on how that dimension affects the overall case dynamics.

Whilst it is impossible to describe all aspects of a case, it is necessary to as far as possible account for all relevant aspects. What aspects are relevant will follow from literature and theory, or from the emerging understanding of the cases. Thus, this is a matter both of selecting cases, and of analysing the cases once the data has been collected. Regarding case selection the task is to find cases that are both sufficiently alike to be comparable, and different in interesting ways, with interesting being determined by theory and literature. This is called theoretical replication (Yin 1994:46).

The overall set of possible cases that could have been chosen is called the sampling frame (which should not be taken to refer to any statistical sampling method) (Miles and Huberman 1994:29). In this study the sampling frame is: large investments in process technology in medium to large sized firms in process industries in Sweden and Scotland. We shall return later to the decision to avoid small projects and small firms. Here, let us just say that the focus on process technology as used in process industry firms gives us cases which are relatively comparable in terms of technology, as compared to the technology used in other manufacturing or service firms.

The choice made was to select cases from two different process industry sectors and two different countries. This way it was possible to control for each of these dimensions whilst analysing the other. For example, we could compare cases between the two industrial sectors within the same country, thus exposing sectoral factors that were at work irrespective of nation.[59]

With this combination of sectors and countries we have a combination of similarities enhancing comparability and interesting differences. Starting with the country dimension, cases were selected from Scotland and Sweden. A complication here is that Scotland is part of the UK, which matters in terms of the organisation of environmental policy implementation. We shall return to this issue in the context chapter.

The two countries have somewhat different regulatory regimes because of a history of higher environmental policy ambition levels in Sweden (Connelly and Smith 1999:295; Midttun and Kamfjord 1999:875), although decreasingly so because of EU harmonisation. This difference is in part due to neocorporatist inclusion of environmental movement organisations in Swedish environmental policy-making (Connelly and Smith 1999:296), and has co-evolved with somewhat stronger pro-environmental attitudes among the Swedish general public (as will be discussed in chapter 5). Regulatory differences are likely to impact on the compliance behaviour of firms. Environmental attitudes among the public may also matter directly for innovation work, insofar as they are expressed at work.

A further difference between the two countries is to be found in their structures of occupational formation. The UK has a much more elaborate organisational set-up for the formal recognition of skills acquired through experience, as well as for protecting and promoting the status of occupational groups, whereas in Sweden such groups rely more exclusively on the attainment of higher education degrees for the protection of their status. This difference between the two countries may relate to the UK having a weaker employment protection and a higher labour mobility between

[59] A potentially complicating factor here was the international character, mostly through ownership, of some of the companies. Both the Scottish cases were in companies with operations also in England. In the case of Chemicals Scotland, the headquarters and the owners were in England rather than in Scotland. This is one of the ways in which the Scottish cases are British rather than Scottish (we shall return to the issue of the possibility of analytically separating out Scotland from the rest of Britain in the next chapter). The Swedish dairy case was ‘all Swedish’, whereas the Chemicals Sweden case was in a company that had been set up in Sweden, and subsequently bought by a Dutch concern. For the purpose of our comparison, we can note that there was no case of ownership relations between Scotland and Sweden.

firms, making formal recognition of skills and experience more important for both employees and employers (this will be discussed in more detail in chapter 5). The difference in the structures of occupational formation in the two countries may matter for how expertise is formed in firms, as well as for any policies addressing the formation of expertise.

As regards the sectoral dimension, cases were chosen from the chemical and the dairy industries. As mentioned above, both are process industries, which will facilitate comparison in terms of the technology used (although there are nevertheless considerable technological differences, not least within the heterogeneous chemical industry). Interesting differences are found in their environmental performance with the chemical industry having a much larger environmental impact, and a longer history of exposure to environmental regulation and stronger environmental pressures.

Other process industry sectors than the dairy sector could have been chosen as a contrast to the chemical cases. In actual fact a case study at a paper mill was initiated, but the company soon went bankrupt and the initial contact persons with whom access was negotiated no longer worked there. Attempts were also made to gain access to an oil refinery, but they were not willing to grant it.[60]

By this choice of cases, we were thus hoping to shed light on the importance of some of the contextual dimensions of the cases, both in terms of the outer context, notably regulation, and the inner context of environmental capabilities. Further, it was the intention to study the role of the historical (decades rather than centuries) development of environmental work and technology in the organisations. Using a comparative approach will in this way enable us to study the contextual and processual aspects of the cases, linking data with the theoretical perspective set out above, contributing to analytical generalisability (Yin 1994:30).

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[60] Also, access was negotiated with a waste management company, which could have been interesting in that the business idea here involves an environmental service. Contacts were also made with electronics manufacturing and mechanical manufacturing companies. Apart from access problems with some of these companies, it was decided to delimit the selection to process industries to improve comparability between cases.

4.2 Data collection

Having presented the major choices regarding the framework of the research design, this section will present the detailed design of the empirical part of the project. The first two sub-sections are about how firms and investment projects were identified, selected and gained access to. The next three sub-sections justify the choice of interviews as the main method of data collection, and discuss identification of, selection of and access to interviewees. These sub-sections also deal with issues relating to interview questions, the roles of interviewees and the interviewer, and practical aspects of recording and transcribing the interviews. The last sub-section is about the use of documents in this study.

4.2.1 The companies

Apart from choosing particular process industry sectors in Scotland and Sweden, one more criterion was applied when identifying possible case study companies. Since the study would focus on certain categories of staff, not least engineers and environmental staff, it was decided to avoid small companies who might not have such employees or very few.

Potential case study companies were identified in several ways. One case was identified through the supervisors of this project, who had studied this company before (see below, in the section Documents). The other cases were identified using the internet, or via colleagues at VINNOVA – The Swedish Agency for Innovation Systems, where I worked prior to and part-time during this research project.

Initial access was gained by calling the company switchboards and after explaining my purpose, asking to talk to someone who might be relevant. The initial contact persons turned out to be environmental or technical managers (some of which had responsibilities in both areas) in all cases.

Some companies (initial contact persons) said no to my request for access.[61] More than ten companies were contacted in all, many of which granted access. Several companies that granted access were later discarded: the paper mill as described above, but also some UK dairy companies since one such was deemed sufficient.

Negotiating access in some cases involved agreeing to conditions set by the companies. This mainly regarded a promise to send them case reports for scrutiny to make sure that no details were included that would expose business secrets. In one case this also included keeping some of the technological details of the production process and the investment project secret. This was deemed acceptable for the purposes of the study, and has not hampered the analysis. All companies are also anonymised in this thesis.

[61] In most cases, once access was initially negotiated, that was the end of this problem. However, in one case access was later withdrawn. This relates to the Chemical Scotland case, and the reason stated for withdrawing access was not clear, but related to my attempt to contact Scottish Environmental Protection Agency (SEPA) to interview the company's contact person there about the project studied. Negotiation was on-going with the SEPA officer, and I had on his request sent an email to him outlining the areas I wanted to talk about. It transpired that he had then contacted the company to enquire what was going on. When the company heard his version of events and about the email I had sent there had been friction between the company and the regulator, and this issue had been taken to higher levels of authority in each organisation before it could be settled. The company then contacted me and let me know that I was no longer welcome. Nor, I understood, was it now possible to talk to the regulator.

It is still not clear to me why this happened, or why the email in question caused this rather drastic reaction. The email was phrased in a relatively open and informal manner, and did suggest that the regulator officer might have a different perspective on the project than company staff. Perhaps it was naïve to think that it was possible to be so straightforward in writing. This was the first of the case studies performed, and care was taken in the later cases to be more diplomatic.

The damage to this research project was limited. It would have been useful to do a few more interviews on the case, and to talk to the regulator, but it was nevertheless possible to use the case study with the information gained from previous interviews.

This event is also interesting in that it appears to tell us something about the relationship between the company and the regulator. On the one hand the relationship was close and good enough for the SEPA officer to contact the company and discuss my attempt to get in touch, on the other hand the relationship appears to have been relatively fragile, if my email could have had this impact. It also appears to testify to the importance placed by the company on the relationship with the regulator. The company went to some length in trying to repair the damage done to the relationship.

4.2.2 The innovations

The unit of analysis, as stated above, is the choices made relating to investment projects. A few more things need to be made clear about how such projects were chosen.

Firstly, we discussed above the importance of studying environmental intentions and environmental outcomes as separate phenomena, and to study them in the context of other intentions, and other technological practices than those explicitly labelled environmental. This is to avoid what could be called using a 'green lens', that is, studying only environmental aspects of firm activities without making clear how they fit in with other aspects. Such an approach is likely to lead to deterministic outcomes, predicting ever-improving environmental performances.

This is akin to Bloor's 'symmetry principle' (1976:5), which states that the same types of causes should be used to explain the development of true and false scientific beliefs. Here we would insist that we need theories that can explain not just 'best practice' cases of environmental innovation but also less green outcomes.

This has consequences for how projects are chosen in this study. It is worth noting that the unit of analysis is not framed in environmental terms. The reason for this is that we should not uncritically accept the firms' accounts of 'best practice environmental innovations' which give rise to improved environmental performance and which were driven by environmental (including compliance) motives. A core question of this research project is exactly how and when intentions and outcomes relate to each other, and so it becomes problematic to use this as a means of identifying projects for study.

When discussing with firms what projects to chose for this study, efforts were therefore made to explain that projects that were seen by the firm as representing good practice or large environmental improvements were not the only projects of interest. The projects finally chosen are a mix of projects in terms of environmental ambition levels and environmental outcomes.

Secondly, projects involving only end-of-pipe technology were avoided. Such projects were attractive candidates in that they most likely had a strong component of environmental intentions, but were nevertheless rejected in favour of projects involving both core technology and end-of-pipe technology. A main reason for this was a perceived risk that such projects would be managed too separately from the rest of the organisation. One of the benefits of end-of-pipe technology to companies is just this, that it can be installed without major disruptions to operations. By including core technology it was guaranteed that the projects would be central to the organisation. Core technology is also likely to be more important economically to the company, and was judged to be more interesting in terms of studying the limits of integrating environmental intentions. Each project chosen is mixed in terms of core and end-of-pipe technology.

Furthermore, small projects were avoided to make sure that there were enough staff involved to have ready access to interviewees (compare the criterion of large firms above) and to study projects central to the organisation. The projects studied are all large investment projects.

The choice was made to study investment projects rather than technology development projects. The main reason is the former's direct relevance to the actual environmental impact of technology 'in action' in firms. Technology development and even research are also interesting but that is for another study.

The investment projects were identified in discussion with the interviewees, most often the first person contacted. Typically a number of projects were discussed and it was up to me to choose, based on my understanding of what was relevant. In one case, Chemical Sweden, the contact person listened to my account of what I was interested in, and later came back to me proposing two projects, one regarding an investment in a plant and one about the development of a new product. The plant investment was deemed interesting.[62] This identification procedure may help in explaining the relatively high environmental ambition seen in this case, as compared

[62] Two interviews were done regarding the product development project before dropping that case in favour of the process technology one. Those interviews were nevertheless useful for background information about the organisation.

to the other three. The company probably wanted to promote a relatively 'green' project. The total set of cases, as mentioned before, is a mix of projects with different ambition levels.

Within the projects chosen, it was necessary to select what choices to study. Such large projects of course involve many choices on varying levels of detail or aggregation, and not all can be studied here. A few different criteria were used to identify choices for study. Of obvious interest is the decision to initiate the project in the first place. Further focus was achieved by asking about choices of relevance to different environmental aspects (releases to air, to water, energy usage etc.) of the projects, both as identified by the interviewees and after probing when some aspects were left out. For example, energy usage was not always spontaneously mentioned by the interviewees as an environmental aspect. Efforts were also made to cover the main technological components of the projects.

4.2.3 The interviewees

The interviewees were identified as the case studies were carried out ('snowballing', Berg 1995:206), starting with people identified by the first contact person in the firm. Access to interviewees was facilitated by entering the company at a management level (Arksey and Knight 1999:64, 123). Often the first contact person let other interviewees know I would get in touch with them, and the authority of a manager gave my contacting them added legitimacy. Access to staff was generally not a problem, once past the initial gatekeeper.

A first criterion when selecting new interviewees was their involvement in the project studied. In particular, the project leader for all cases was interviewed. In a few cases interviews were done with people who had no or little role in the projects. In the Dairy Scotland case no environmental staff were involved in the project, but an environmental staff member was interviewed anyway for contextual information regarding the environmental work in the company, and with the question in mind of why he was not part of the project. In the Chemicals Sweden case some of the interviewees were involved in another project, but provided useful background information about the organisation.

It was not possible, nor necessary, to interview all project participants. A selection was made to cover the main categories of staff potentially involved, as identified in the literature review: engineers, environmental staff, managers and workers. Thus the main areas of expertise, and different hierarchical levels were covered.

The managers interviewed were located as high up the company hierarchy as the Technical Managers and Division Managers. Most managers were lower in the company hierarchies. Even though some decisions were made high up in the management structure, priority was given to those substantially involved in the projects. The reason for this was to talk to individuals with a thorough insight into the projects. It was also hoped that interviewees lower down in the hierarchies would put somewhat less ‘spin’ on their accounts of the cases, and give straighter answers.

The categories of interviewees to include changed somewhat over the course of the project. The aim to include operators and union representatives was eventually dropped. Firstly, this was done because relatively little relevant information was gained. Few of the unions interviewed, for example, had any interest in or much knowledge of the environmental aspect of the projects. Secondly, this was done because excluding the issue of worker participation allowed a sharper focus on the core categories of participants: engineers and environmental staff.

In contrast, a new category emerged during the project. Part of the project work was done in three out of the four cases by external consultants (or equipment supplier staff doing design-type work for their customers). This was mainly engineering consultants, but to a smaller extent also environmental consultants. Consultants were interviewed in these three cases.

In addition to those involved in the projects, interviews were also made with the companies’ main contact persons at the environmental regulator in each case (apart from the Chemicals Scotland case, see footnote 61). The regulator staff were identified via firm interviewees, or via the regulator's switchboard. The companies agreed to me contacting regulator staff.

This was done to gain a potentially different viewpoint from the one of the firm regarding the environmental aspects of the investment projects, and the company's environmental performance in general. The regulator staff were also a useful source regarding details of environmental permits and permit application processes.

The regulator staff were useful interviewees in that they had some insight into the company and – to varying degrees – the projects, whilst at the same time being on the outside of the firm and thus having somewhat different commitments. Although, as the Chemicals Scotland case illustrates, they also place value on maintaining their working relationship with the company, and this might have limited the amount of criticism of them revealed. A similar thing can be said about consultants and supplier staff, who when involved in the projects had good insights, but also are employed outside the firm. Here, repeated contracts and hopes for future work may have coloured their replies.

The interviewees were thus selected in part to represent the actor categories identified in the literature, and in part to explore those actor categories actually involved in the cases studied (Arksey and Knight 1999:52). All in all 43 interviewees were done. Between 8 and 14 per case, depending on access (in particular in the interrupted case of Chemical Scotland) and on how many people were involved in the project. The interviewees are listed in Appendix A.

4.2.4 The interviews

Data was collected primarily through semi-structured interviews. This was deemed suitable for the qualitative information sought, and for the potential to clarify and elaborate issues during the interviews given the complex, contextualised nature of the topic (May 1993:93). It would have been possible to choose a participant observation method instead, but it was judged that interviews would give enough detail and insight, and the more time-consuming option of participant observation was therefore not chosen.

Another alternative would have been survey research. Given the aim to thoroughly contextualise the topic, surveys were not suitable as a main method of collecting data. However, using surveys in conjunction with interviews was considered, especially for questions regarding the interviewees' private life environmental values and behaviour (see below). A survey would have given more easily comparable data, but as Crane has pointed out, criticising the predominant positivist approach of business ethics research, ethical concepts also need to be understood in context, and there are risks about developing questions prior to data collection (1999:245). It was therefore decided to stick with the interview method, and to combine an open-ended question about private life environmental values, with more closed, and comparable, questions about membership in environmental movement organisations, and household behaviour.

The research questions were designed to elicit the information necessary to answer the research questions. A set of themes were developed and made part of an interview guide. The themes of the interviews are listed in table 4.1.

A few comments may be made regarding the interview themes. We have already discussed above how different environmental and technological aspects were identified in dialogue with the interviewees. We have also discussed previously which categories of staff the case studies sought to cover, and that each interview offered opportunities to identify further potential interviewees. Also, some of the themes cover the recent history of the firms and the interviewees. These themes were included to strengthen the processual aspect of the analysis. The interview themes are also overlapping. For example, the interviewee's background can be seen as part of the inner (history of work in the organisation) and outer (education, private life issues) context.

Table 4.1 Interview themes

Major themes	Sub-themes
Project	Aims, outcomes, technological and environmental aspects, project organisation
Choices	Options, motives, actors involved in decision-making
Inner context	Company organisation, engineering and environmental work and expertise, history of engineering and environmental work
Outer context	Markets, regulation
Actors	Organisational position, roles in project, careers and education, private life environmental commitments, interaction between staff and consultants

These themes were quite stable over the duration of the project, with the emergent theme of interaction between staff and consultants as a major exception. Also, in each case more specific, detailed themes emerged. For example, the timing of the increased regulatory pressure in the Dairy Scotland case, or the vent gas conflict in the Chemicals Scotland case.

The interview guide was structured in three parts. The major middle part was about the case project, and here most of the themes tabled above were covered. The first and third part were about the interviewee:

1. the interviewee's position in the organisation,
2. the case project, including the interviewee's role in it, and
3. the interviewee's background and private life environmental commitments.

The first part contained relatively easy questions to break the ice (Arksey and Knight 1999:98). In the middle part more use was made of probing, follow-up questions to elicit more detailed answers (May 1993:93; Robson 1993:234). The parts about the interviewee were the most structured parts, mainly asking for basic facts about the interviewee's position, previous jobs etc. It was made explicit at the start of each interview that the interviewee did not have to answer the questions if they did not want to.

There is a sense in which the interviewees were prompted to perform two different roles. Firstly, their role as defined by their position in the company and experience from the case project – they here represented themselves as employees and representatives of the company. Secondly, they were asked about their background, including their education and any career before being employed in the case company, and also about their private life environmental commitments – it was here my intention to induce them to perform a role more independent of the company context. This does not mean that I could control which role they played. For example, in a few cases, the interviewees were not comfortable talking about their private life values, and preferred expounding on the company policy. The professional and the private roles are also not independent; we bring private life concerns to work and vice versa. Care had to be taken interpreting the interviewees' statements when trying to distinguish between their private and professional roles.

A further complexity, given the comparative approach chosen, is to distinguish between national culture and other individual commitments. Not least for the sensitive questions regarding private life environmental values and behaviour the interviewees' responses are likely to be influenced by what is seen as correct behaviour in each country. The generally somewhat stronger environmental awareness in Sweden as compared to Scotland coloured the replies of the Swedish interviewees relative to the Scottish ones.

We should avoid seeing these influences as biases, although it may be tempting to talk here of political correctness and 'business correctness'. We should not try to see the 'true' individual behind the roles, with the residual individuality being what is left when biases are stripped away. It is more appropriate to see this as consequences of the different roles people play, and investigate how these roles work and affect the cases. It was also not the case that the interviewees were 'victims' of these different cultural spheres; they were also quite capable of expressing different and diverging opinions.

To properly understand and account for these interviews, it is necessary also to look at the roles I played. At the start of the interviews, apart from presenting my research project, I presented myself and my background briefly. This included mentioning my degree in engineering, with the intention to gain a degree of trust from the interviewees, many of which had engineering and science backgrounds. In Sweden, I could also mention my previous employment at VINNOVA as a means of gaining some respect (hopefully?), and so counteracting my relative youth as compared to many, but not all, the interviewees. As part of this status game I dressed in a suit to appear more business-like, and to show respect for my interviewees (Arksey and Knight 1999:104).

In the case of the UK interviews, my foreign background was apparent to the interviewees, and I clarified this as being from Sweden. My language skills were not generally an issue, although some minor problems were encountered in some cases with interviewees with strong regional accents. In those cases, transcribing the interviews took longer time. This was also an issue of cultural background knowledge, and asking again about some things that I would have known about had I been British. An example could be the differences in how the engineering profession is organised (as explained in the chapter 5). I had to learn these things as I went along, but they did not present any real obstacle to the interviews.

A potentially bigger problem was being seen as 'green'. This was inevitable given the topic of the interviews. I tried to downplay this by explaining that my research interests are not about finding faults with anyone or exposing the companies. This was at least not counter-productive, but the interviewees clearly saw me as being environmentally committed. The effect of this was not too big, as some of the interviewees were quite comfortable saying that environmental things were not that important.

4.2.5 Handling the interview data

Most interviews (35) were performed visiting the organisation in question, although a minority of interviews were done via telephone (8). This was done for practical reasons, as in some cases the interviewees of a particular case were geographically spread out, and the time and cost requirements of visiting everyone were prohibitive.

Approximately two thirds (27) of the interviews were recorded. This was done for several reasons, firstly, so as to be better able to concentrate on the dialogue (May 1993:104), but also to facilitate detailed recall after the interview and be able to provide truthful quotes. The interviewees were asked for permission to record.

A total of 16 interviews were not recorded, which includes the eight phone interviews. The remaining 8 interviews were not recorded for a series of other reasons, each happened in a few cases:

- the interviewee did not consent to this procedure;
- the interviewee was perceived to not be very keen on the interview, and it was judged better to keep them as informal as possible;
- the room was too noisy;
- the recorder did not work.

When the interviews were not recorded, extensive notes were taken (apart from one or two very annoying cases when the recorder did not work). Further detail was gained from offering the interviewees the opportunity to read the transcribed interviews, and in a few cases by calling the interviewee after the first interview to ask further questions.

The interviews were transcribed in full, or written up from notes and memory as soon as possible in the cases not recorded. This was done to get full use of the recordings, and to facilitate the analysis. All the interviews were transcribed in the language in which the interview had been done. Translation of the Swedish interview data was done where necessary, for example for quotes, during analysis and writing.

All the interview transcripts were sent to the interviewees. As full transcripts are lengthy documents, sometimes abbreviated versions were sent to the interviewees to increase the chances of them reading the transcripts and of getting feedback. The shorter versions then focussed on the most important parts of the interviews. Sending out the transcripts was also an opportunity to ask more questions. I often included questions in the transcripts asking for more information. Some of the interviewees wanted to comment on the transcripts and others not.

Sending out the transcripts was also done partly as a courtesy to the interviewees. They were given the chance of pointing out if they did not want me to use particular statements, or facts about the company. This was rarely the case, however, and has not affected the analysis. All interviewees are also anonymised in this thesis.

4.2.6 Documents

The main source of data was interviews, for reasons described above. Some use was, however, also made of documents.

Firstly, to describe the sectoral and national contexts of the cases, publicly available sources were used, rather than interview data. Some of the interviewees talked about this, but the focus of the interviews were the projects and the inner context of the respective organisation, for which there are little publicly available sources. The main sources used were academic papers and books, as well as reports and information material from public and private sector bodies.

Secondly, some documentary sources were used also for the cases. Effort was made to get copies of the relevant environmental permits to corroborate the interviews. Copies were attained either from the companies or from the regulators for all cases (apart from Dairy Scotland who was not at the time required to have an environmental permit).

One other category of documents was systematically sought: descriptions of project and firm organisations, to get concise and accurate information about the formal organisations. This was not always possible though. Some firms did, perhaps surprisingly, not agree to make such documents available.

Apart from this, various other firm documents were made available on an ad-hoc basis. This material ranged from company presentation brochures obtained in receptions waiting for interviews, to certain project documents made available by helpful interviewees. The later type of documents was typically presented to me as a help for the interviewee to explain the projects, and was in this sense part of the interview data.

It is worth noticing here that, as described above, the supervisors of this thesis had done a case study at Chemicals Scotland previous to my case study. This case study has been published (Clayton *et al*. 1999:96) and could be used when writing the current case study. Also, the interview transcripts for the old case study were made available for renewed analysis. This could have strengthened the processual perspective, but the questions asked were not similar enough to allow comparison over time, and did not contribute very much more to this project than could be learnt from the published case report.

4.3 Analytical methods

Analysing qualitative data can not be done in a mechanical fashion. Part of the analysis process is about immersing yourself in the data (Berg 1995:180) to gain an understanding of the cases that way. The actual transcription of the interviews was helpful in this respect. Systematic analysis is, however, indispensable. Systematic analysis will help stimulate new insights and reveal new relationships in the data, but also help verify or undermine the understandings and impressions of the analyst.

Several tactics were employed for a systematic analysis. Firstly, the interview data was coded, based on the interview transcripts and documents attained from the interviewees. The full text pertaining to each theme was then cut and pasted into a new computer document for each code. Sometimes it was useful to break the material down further into more fine-grained coding categories, and the procedure was then repeated for each sub-code. This was done to gain an overview of the categories, themes and patterns (Marshall and Rossman 1989:114; Arksey and Knight 1999:169) of the data.

To an extent it was possible to use predetermined codes mirroring the questions of the interview guide that was designed prior to data collection. There were, however, also emergent themes, requiring new codes, whereas other codes were dropped as the project progressed. This relates primarily to the dynamics of the interview themes, and categories of interviewees as described above.

The cases were written up as case stories (Yin 1994:104; Arksey and Knight 1999:169), focussing on the choices and decisions made and the roles of the actors in the innovation processes. The case stories also include the inner context of the organisation and its recent history, as well as some information regarding the outer context: markets and, not least, regulation.

An alternative to writing case stories would have been a cross-case thematic exposition. Whereas this could have been a useful way of setting up the subsequent analysis, it was felt that the contingencies of each case might have been lost in this format, and the comparative analysis was written up separately. This solution requires somewhat more repetition of the case data, but that is a price deemed worth paying to maintain the integrity of the cases, and avoid decontextualisation (Arksey and Knight 1999:168).

An important part of the analysis is comparing the cases. Clear differences were for example found between the chemical and the dairy cases, in terms of the timing when environmental regulation had started exerting pressure on the companies, which had consequences for the career patterns of the staff.

Extensive use was made of matrices, tables, diagrams etc. in the analysis process to visualise and get an overview of particular aspects of the data, as well as to test emergent hypotheses and search for alternative explanations (Marshall and Rossman 1989:114). Some of the more useful ones of these can be seen below in the analysis chapter.

4.4 Conclusion

The first research question relates to the impact of environmental intentions on technological outcomes. The methodological strategy to answer this question includes a contextual and processual perspective, within which to study the relationship between intentions and outcomes. Further, the unit of analysis was not chosen in terms of the environmental dimension, so as to allow the study different intentions and outcomes, and to see how environmental intentions relates to other intentions etc. With regard to case selection, not only 'best practice' cases were chosen, to avoid pre-judging the environmental character of the projects, and the relationship between environmental intentions and environmental outcomes. Finally, the set of interview questions includes questions regarding both intentions and outcomes.

The second and third research questions are about environmental promotion and its structured organisational context. This leads us to study the different voices of the actors in the firm, and to look for potential areas of conflict between them. Different categories of actors in the firm were chosen for interviews, covering both different areas of expertise, for example engineers and environmental staff, and different hierarchical levels in the organisation, for example managerial and non-managerial staff. Also, the interviewees were asked about any private life environmental commitments that may or may not influence them at work. Furthermore, interview questions regarding decision-making, as well as the organisational setting – in which context decision-making happens – and its recent history, were included to enable analysis of organisational structures.

This contextual, processual and political approach leads to a choice of a qualitative approach, based on case studies and semi-structured interviews. A comparative approach further strengthens the contextual and processual analysis.

The approach chosen reflects personal commitments to the environmental cause, as well as a political outlook. Efforts were made to manage the impression of being 'green' in the interview setting. Some such impact was unavoidable merely from approaching the interviewees about the chosen topic.

Efforts have been made to treat the informants fairly. Firms and interviewees are anonymised in the written outputs. All interviewees have been given the chance to read transcripts from their interviews.

The use of an interview guide and a coding procedure for the analysis has contributed to the reliability of the research. The validity has been enhanced in various ways. That the case narratives relate well to the reality of the interviewees, is guaranteed by interviewing several people about the same case, and having given company representatives the opportunity to read the case studies. That the analysis provides valid explanations has been secured by the explicit comparative analysis, as well as iterating parts of the case data to back up cross-case conclusions. Finally, the theoretical framework developed is adapted to large investments in process technology in medium to large sized firms in process industries in Scotland and Sweden, and the results are valid primarily in this domain (Yin 1994:33).

5 Setting the scene – countries and industrial sectors

This chapter will set the scene for the comparative analysis. We shall in the analysis compare two countries - Scotland and Sweden - as well as two industrial sectors: the chemical industry and the dairy industry. Here, we shall begin by discussing relevant aspects of the two countries, to be followed by the two sectors.

5.1 Countries: Scotland – Sweden

We are in this study concerned with two countries: Scotland and Sweden. These are two small European countries with 5.1 and 9.0 million inhabitants respectively (GROS 2006:6; SCB 2005b:40), and with similar levels of economic wealth: £16 200[63] and £20 400 per capita (Scottish Executive 2006a:5; SCB 2005b:40).

An important difference, however, is that whereas Sweden is a state, Scotland is a nation[64] within the United Kingdom.[65] This matters to comparisons of the two countries, and sometimes it will make more sense to compare Sweden with the UK as a whole, and sometimes this will be the only feasible thing to do because of a lack of data specifically on Scotland. But sometimes this will not be acceptable for the purposes of this thesis.

For example, we shall need to study environmental regulation separately, since it differs between Scotland and the rest of the UK. It is a so-called devolved issue, (Scottish Executive 2006b) meaning that the policies implemented in Scotland are made by the Scottish Parliament rather than by the UK Parliament.

Apart from this difference in the formal governance structures, Sweden and the UK/Scotland are also rather different in terms of political economies. Using the

[63] GVA in 2004. The Scottish Executive report Gross Value Added, rather than GDP.

[64] Scotland is a nation, rather than a country. We shall here mostly refer to it as a country for the sake of convenience in comparing it with Sweden, which is a country (and, arguably, a nation).

[65] For Swedish readers: The United Kingdom (UK) consists of Great Britain and Northern Ireland. Great Britain, in turn, consists of England, Wales and Scotland.

dichotomy set up by Hall and Soskice (2001:8) Sweden can be characterised as a 'coordinated market economy' as compared to the 'liberal market economy' of the UK.[66] This distinction refers primarily to the means through which the economy is coordinated. In an ideal-typical liberal market economy this is done through formal contract-like economic relations, and in its 'opposite' through informal network relationships (*ibid*.:8).

The state also has quite different roles in these two types of market economies. In a coordinated market economy like Sweden the state is more directly involved together with industry organisations and organised labour in the coordination of (industry- or sector-wide) industrial structures. In contrast, in a liberal market economy like the UK the role of the state becomes more that of the securing of framework legislation to enable markets to function (Wood 2001:251).

The UK underwent a dramatic development during the 1980s and 1990s, bringing it closer to the ideal-type liberal market economy (Coates 1999:652). For example, trade unions had more influence on policy before the Conservative governments of the period (Taylor 2001:11). Like in the UK there has also been a shift towards increased market liberalism in Sweden during the 1980s and 1990s, but with much less dramatic effect. For example, formal corporatism has ended and labour organisations have less influence on policy, but not radically so and the biggest change is perhaps the more informal way in which corporatism now works (Svensson and Öberg 2002:310).

To be more specific the Swedish regime can be characterised as neo-corporatist, reflecting the participation in policy-making by other organised interests than capital and labour. Connelly and Smith (1999:296) have described the comparatively large role of the environmental movement in policy-making in Sweden (as we shall discuss more below).

[66] There are many alternative models to characterise different types of market economies. For example, Coates (1999) argues for a 'triangular' model encompassing a third state-led, conservative model (closely modelled on Japan) in addition to the market-led, liberal and the labour-led, social democratic ones, which are similar to the models of Hall and Soskice above. Hall and Soskice's model appears to be well suited for the Sweden-UK comparison though.

A fundamental aspect of the differences between liberal and coordinated market economies is the role of organised labour in labour markets, and here the two countries are distinctly different. Sweden has strong employment and unemployment protection (Estevez-Abe *et al*. 2001:165, 168) and strong labour unions (high trade union density, Hall and Soskice 2001:59). And although wage bargaining has been decentralised from national to sector/firm level (Thörnqvist 1999:81-82) co-determinism in the workplace is still strong (Levinson 2000:472). In contrast, in the UK employment and unemployment protection is weak (Estevez-Abe *et al*. 2001:165, 168). Rates of trade union membership and workplace presence are low, especially after having been substantially reduced during the 1980s and 1990s (Taylor 2001:6). The trade union influence in many workplaces is weak even where there is union representation (Terry 2003:487).

These differences in the workings of labour markets matter for occupational formation, as we shall discuss below. We shall in particular describe some differences in the labour markets for engineers and environmental staff in the two countries. After that we shall compare the environmental regulatory systems of Sweden and Scotland, and the environmental attitudes and behaviours of the two populations.

5.1.1 Occupational formation

The different roles of labour are a reflection (and a cause) of the different ways that labour markets and skills formation work in the UK and Sweden. As compared to Sweden the UK economy with its low employment and unemployment protection favours high labour market mobility and the development of general skills (Estevez-Abe *et al*. 2001:170). In contrast, in Sweden there is lower mobility (longer average tenure) and more investment in sector- and firm-specific skills, through for example a larger fraction of the population obtaining training from vocational colleges (*ibid*.:170)

For the individual this also translates into a stronger orientation towards careers (in terms of moving between firms) in liberal economies, as compared to commitment to firms (or lock-in) in coordinated economies (Hall and Soskice 2001:40). This may go some way to explain the differences in the occupational formation of engineers and environmental staff discussed below.

We shall describe here some differences between the two countries in terms of the work and occupational formation of engineers and industrial environmental staff. The focus will be on, not least, the differences between the two countries in the organisational set-ups for protecting and promoting the status of these occupational groups.

5.1.1.1 Engineers

'Engineering' and 'engineers' are relatively well-known phenomena (Whalley 1986; Vincenti 1990; Sørensen and Levold 1992; Bucciarelli 1994; Downey 1998; de Vries 2003) and will not be described in all their aspects here. We shall instead focus on a few national differences.

The balance between engineers and scientists is different in the two countries. A larger share of those with a tertiary education in the UK holds a degree in science as compared to Sweden. In Sweden a much larger share hold an engineering degree. See table 5.1. This suggests that there are more scientists employed in the UK industry than in the Swedish one, and that some work that would in Sweden be done by engineers is done by scientists in the UK.

When comparing the qualifications of engineers in Sweden and the UK, it should be noted that the UK system is much more complex than the Swedish one. In Sweden an engineer will have an educational degree in engineering (upper secondary[67] or tertiary[68] level or a research degree) typically attained from full time studies. In the UK there are, apart from such full time educational degrees, also other ways of attaining qualifications. The UK has an elaborate system of certificates and diplomas

[67] Gymnasieingenjör

[68] Högskoleingenjör, eller civilingenjör

(Higher National Certificates, Higher National Diplomas, etc.) typically attained by part-time study.

Table 5.1 Share of those with a tertiary degree, per discipline

	Engineering	Science
Sweden	20.8%	4.8%
UK	9.2%	11.0%

Source: OECD 2005

Notes:

1) Science here excludes Computing, as well as Mathematics and statistics

2) Degrees included are those included in ISCED 5A, for example, MSc and Bachelor degrees, but not Higher National Certificates in the UK, or Lower Level Diplomas in Engineering (Högskoleingenjörer) in Sweden. Including those (ISCED 5B) does not change the overall picture.

In the UK there are professional institutes, for example IChemE (Institute of Chemical Engineers), which organise and protect the status of certain professions and occupational groups. To become a (full) member you need to have certain academic qualifications as well as practical experience (IChemE 2006). This system of certificates, memberships, etc. is not limited to engineering but extends to other vocations. Sweden has no legal protection of engineering titles, and no central certifying body. However, there are two labour unions for engineers who, among other things, may negotiate salaries and conditions of employment for their members (Hamilton 2000:79-80).

In Sweden more people get a vocational engineering education at what Estevez-Abe *et al*. call 'vocational colleges' (2001:171).[69] It appears, however, that the UK system is better suited for giving individuals formal recognition for practical experience. In terms of occupational formation, the Swedish strategy for protecting the title of 'engineer' rests heavily on acquiring degrees, that is on the knowledge base, whereas in the UK there is a much more elaborate formal organisation of the labour market. The somewhat stronger orientation towards external careers of UK employees may

[69] They probably refer to 'högskolor'.

contribute to a greater need for formalised recognition of experience. One may also speculate that in Sweden it is easier to market and evaluate expertise informally through the denser inter-firm networks.

5.1.1.2 Environmental staff

There has been relatively little research done on industrial environmental staff as compared to on engineers. We shall therefore introduce this occupation with a somewhat broader scope, and discuss who its members are, what they do and how their expertise is formed. Given the focus of this thesis, special focus will be paid to ‘environmental engineers’.

By ‘environmental staff’ we refer to firm employees with environmental work as an explicit task. This group refers to those with environmental work as their principal area of work, as well as those for whom it is an additional, secondary task. Therefore, it also refers to people doing environmental work full-time as well as part time. Below we shall mainly be talking about employees with environmental work as a principal area of work. Finally, ‘environmental staff’ includes both managerial and operational staff.

Environmental staff typically have an educational background in science and engineering (NMC 2002:8; White 2006:9). According to White, they have also often studied environmental science or engineering (2006:11).

At managerial level environmental work is often done on a part-time basis (one third of respondents did environmental work full time, NMC 2002:11). Often these managers are also managers of quality and H&S issues (30% and 20% respectively, NMC:11).

To further understand who environmental staff are, we shall look at what ‘environmental work’ they do. We can get an idea about this by looking at what Swedish environmental managers said they did in 2002. Their most common tasks were:

Table 5.2 Most common tasks of environmental managers

Lead the work on the environmental management system
Develop a strategic environmental policy
Support firm management
Motivate employees
Give strategic advice to management
Be an advisor
Be in charge of environmental permits
Be in charge of environmental auditing
Produce environmental reports

Source: NMC 2006:14

The tasks of environmental managers thus include, apart from administrative tasks relating to permits, audits and reports, support and guidance on a strategic level in the firm.[70]

White (see table 5.3) has attempted to categorise the work of environmental staff, based on what he identifies as the direction in which environmental work has developed: essentially away from compliance and end-of-pipe, via integrated solutions, towards work on the level of production systems.

[70] It should perhaps be noted that these data build on a survey to environmental managers themselves. A different picture might emerge if one were to ask their colleagues.

Table 5.3 Type of environmental work

Type	Activities
Traditional	Legal and regulatory analysis, site audits, pollution control, product content changes
Non-traditional	Pollution prevention, waste minimization, resource conservation, chemical use reduction, and design for EHS; product design
Noveau	Supply chain management, technology development, stakeholder communications, corporate governance

Source: White 2006:12

We can observe that although tasks that would appear to demand science- and engineering-type skills are included here, as reflected in the educational background of environmental staff, their work also involves other types of tasks, like communication, management etc.

From these data it would seem that environmental staff in general do more engineering-type work than do environmental managers, although this may also depend on White's study being of environmental staff in the high-tech semiconductor industry (2006:1). More generally, it is difficult comparing these accounts of environmental staff work, since the authors do not clearly define what they consider 'work' to be, and appear to describe it in partially different dimensions. Indeed, what White describes appears to be outcomes of environmental work, rather than the actual tasks.

Nevertheless, we see that environmental staff work involves tasks relating closely to administrative systems: permits, policies, etc. It also appears to involve communicative work: supporting and advising firm management, as well as other functions, including technology, manufacturing, etc.

Environmental staff do not, of course, do all the environmental work. Kvernes and Simon observe that environmental tasks and responsibilities are increasingly integrated into other tasks in the workplace, and the skills profile demanded by employers is primarily an ability to relate environmental issues to the work of other professions and occupations like engineers, managers, lawyers, etc. (2000:5).

This draws our attention to the professionalisation of environmental work, in itself and in relation to engineering. Like in engineering, the UK regime of occupational formation for industrial environmental staff is more complex. A group of UK professional institutes in the environmental area are organised under the umbrella of the Society for the Environment (Soc Env). Through the society individual members can apply for the title of Chartered Environmentalist. This group of institutes include for example:

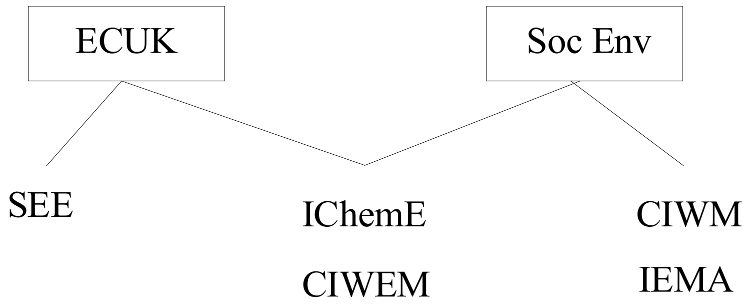
- IEMA, Institute of Environmental Management and Assessment,
- IEEM, Institute of Ecology and Environmental Management,
- CIWM, The Chartered Institute of Wastes Management, and
- CIWEM, Chartered Institute of Waste and Environmental Management (Soc Env 2006).

These institutes have somewhat different profiles. CIWM, for example targets the waste management industry (CIWM 2006). IEMA targets all industry (as well as other organisations), and especially individuals working with environmental assessments or auditing (IEMA 2006).

Soc Env overlaps with the umbrella organisation in the area of engineering: the Engineering Council UK (ECUK), which protects the titles of Chartered Engineer, Incorporated Engineer and Engineering Technician. Several professional institutes are part of both umbrella organisations, including CIWEM and IChemE: Institution of Chemical Engineers (ECUK 2006).

There is a professional institute for environmental engineers in the UK, SEE: The Society for Environmental Engineers, founded in 1959 (SEE 2006). The society is part of the Engineering Council UK, but not, however, the Society for the Environment (ECUK 2006; Soc Env 2006).

Figure 5.1 Selection of UK professional institutes



The Swedish institutional landscape is less elaborate. There are no unions specifically for industrial environmental staff. The main institutions relevant to environmental work in industry are:

- Swedish Association of Environmental Managers (Näringslivets Miljöchefer, NMC), and
- Swedish Environmental Engineering Society, (Ingenjörer för Miljön).

Neither of these, as can be expected in Sweden from our discussion of engineers above, protects professional titles. Overall, we see a much more elaborate and interwoven structure of professional bodies in the UK. See figure 5.1. The dearth of such bodies in Sweden means that the structure of educational degrees and programmes to a larger degree defines the occupation.

There are higher education degrees in environmental engineering, but – at least in Sweden – they lack a clear identity (HSV 2003:8). Having grown out of other engineering education (HSV 2003:7), they are still searching for a clear format that can be more effectively marketed on the labour market. This can be compared with other areas of environmental education, for example Environmental Health, which is a well established route to becoming an environmental health inspector.

In conclusion, it would seem that the occupations of industrial environmental staff and environmental engineers are less well defined in Sweden than in the UK, and at least in Sweden less well defined than that of engineers in general. A further problem in terms of protecting industrial environmental expertise may be that environmental work is increasingly done by other than environmental staff.

5.1.2 Environmental regulation

We shall here compare the regulatory regimes in the two countries, starting with the background in terms of a brief historical account. Thereafter, we shall look at formal (organisational structures and content) and informal (styles and tactics) aspects of regulation.

Sweden is among a group of Northern European countries with a reputation for pioneering environmental policies (Connelly and Smith 1999:295; Midttun and Kamfjord 1999:875). The UK has historically had a stronger orientation towards demanding a well established scientific basis for its regulation, and towards taking the varying assimilative capacity of the recipient environments into account, as compared to Sweden where the precautionary principle has had an impact for a longer time and regulation has aimed towards always reducing pollution at the source irrespective of the specifics of the locale (Clayton *et al*. 1999:34; Honkasalo 2003:27). The UK has effectively been a follower, and EU regulation has had a large (larger) impact on UK environmental regulation over the last two decades (Connelly and Smith 1999:298).[71] EU harmonization has also meant a shift in the UK away from the recipient-oriented approach towards source reduction (Clayton *et al*. 1999:40).

Both Sweden and the UK have moved from regulating pollution per medium: water, air, etc., to so-called integrated permitting, to reflect that many processes affect more than one medium and to avoid polluters shifting their pollution from one medium to another. Sweden has had integrated permitting since the 1960s (Honkasalo 2003:26-27). (Further integration of environmental legislation was achieved through the Environmental Code of 1997, Lundqvist 2000:24).

[71] Although the recent (late 90s) IPPC regulation to come out of Brussels was modelled on the UK IPC regulation (Connelly and Smith 1999:308).

The UK introduced integrated permitting in 1990 (Honkasalo 2003:26-27) through the Environmental Protection Act (Connelly and Smith 1999:303). With the Environment Act of 1995 the UK also got an organisationally integrated system with the creation of the Environmental Protection Agency (EA, for England and Wales), and the Scottish Environmental Protection Agency (SEPA), both of which were established in 1996 (Blair 1997:93; Connelly and Smith 1999:305).

5.1.2.1 Organisational structures and content of permits

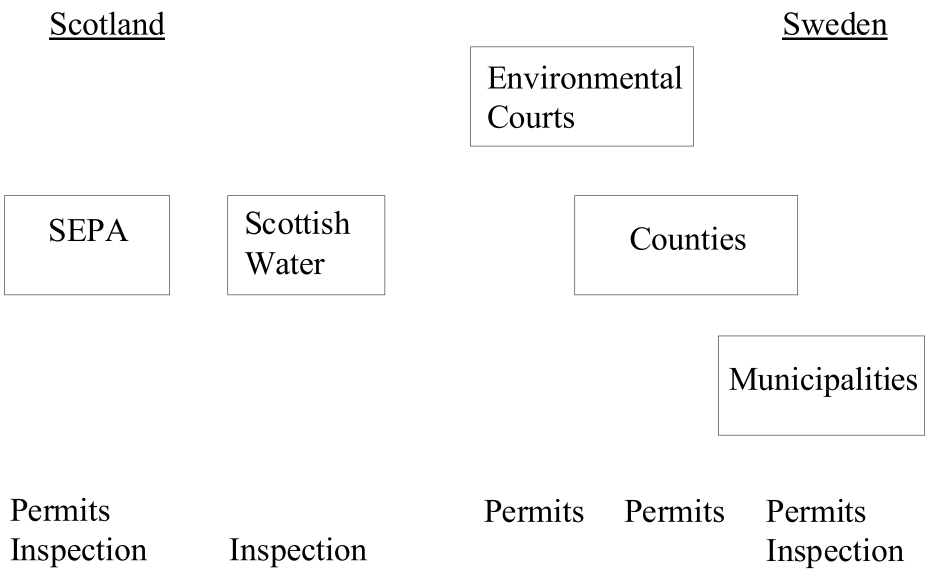
The Swedish organisation of environmental regulation is fragmented (Connelly and Smith 1999:300) and devolved (Fudge and Rowe 2001:1530), whereas the Scottish one is (largely) integrated and centralised.

Swedish business operations are classified in three categories with regard to the seriousness of their potential harm to the environment,[72] corresponding to three different bodies awarding environmental permits. The most serious cases are awarded environmental permits by environmental courts (as from 1999). Medium cases are dealt with by county administrations, and the least serious cases are given permits by the local municipality (Connelly and Smith 1999:301), see figure 5.2. Inspection is carried out by the municipalities. The structure is thus fragmented both vertically between the three levels, as well as horizontally, as there are 290 municipalities in Sweden. In contrast, environmental permits are granted by SEPA in Scotland, which also carries out inspections.

The only anomaly to the Scottish system is that Scottish Water, which provides water and manages effluent, is allowed to fine companies in cases where the received effluent threatens the operation of Scottish Water's effluent treatment facilities. Scottish Water may also inspect business operations for this purpose. In Sweden the municipalities are responsible for (and often run) public treatment works. These sewage utilities may, unlike environmental regulators proper, have an interest in maintaining a certain level of effluent for the effective running of the treatment plants. Their primary type of sanction is fines.

[72] A fourth category is those that do not require permits.

Figure 5.2 The organisation of pollution regulation in Scotland vs. Sweden



The content of environmental permits are in many ways similar in the two countries. They will include compliance standards, that is, limits to the discharges of certain substances. Also, in both countries the permits granted are supposed to reflect a compromise between environmental and economic objectives. Swedish regulation weighs environmental concerns against economic viability and best available technology (Connelly and Smith 1999:301). In Scotland the formula for this is BATNEEC: Best Available Technology Not Entailing Excessive Costs (Smith *et al*. 1997:164; Connelly and Smith 1999:303).

Furthermore, when applying for a permit in either country, the company will have to produce an assessment of the environmental impact of any planned releases (Smith *et al*. 1997:168; NV 2001:10). This means that since changes to the production processes may require a new permit, the law requires an assessment be carried out.

A difference between the two countries is that in Scotland the law regulates individual industrial processes (Smith *et al*. 1997:164), whereas in Sweden a permit will cover a production site with one or more processes. Therefore, in Scotland, a firm may need more than one permit per site. This may matter when there is a change to a process (or a new process is introduced). In Sweden, this potentially could lead to a review of the entire permit of the site, whereas in Scotland only the permit for the changed process is affected.

5.1.2.2 Styles and tactics of policy-making and enforcement

Both Sweden and the UK have collaborative styles of policy-making (Connelly and Smith 1999:296, 300; Midttun and Kamfjord 1999:875; Lundqvist 2000:22). In both countries government cooperates with industry in formulating environmental policy. The difference between the countries is the role of other actors, in particular the environmental movement.

The Swedish style can be described as neocorporatist (Connelly and Smith 1999:296). It is here common practice to have large non-governmental organisations (NGOs) as part of government committees developing policy (OECD 2004:129). The UK style has been more closed to other actors than industry. Until recently there has not been much public consultation on environmental policy, and thus less access for NGOs, but this may be changing (OECD 2002:188).

As for implementation of environmental regulation, a distinction is often made in the literature between collaborative and policing-style enforcement. The literature is not quite clear as to how Sweden and the UK (or Scotland) compare on this distinction. Bohne (2001:4) found a more policing-style enforcement in England and Wales, as compared to the Swedish ‘mediating’ style. But, Gouldson (2004:593-594) claims that the enforcement approach in England and Wales became more formalised in the late 1990s and early 2000s. This means that the difference between Sweden and the UK may have varied over a relatively short period, which makes comparison more complex.

Moreover, Lovat (2004:53) found that in Scotland environmental inspectors place importance on a collaborative relationship with operators (Lovat 2004:53). This suggests that there may be a difference between Scotland and the rest of the UK, but without any studies making direct comparisons, such a conclusion is uncertain.

Furthermore, Sherlock *et al*. (2004:660) have pointed out that enforcement style is also a matter of tactics. Inspectors will apply a combination of collaboration and policing in trying to influence firms (Sherlock *et al*. 2004:660). Gouldson (2004) made a similar point, showing how regulators will vary their approach depending on the operator, and change it depending on the operator's response.

An important foundation for a collaborative approach is for the inspectors to have a degree of discretion (Lovat 2004:51). Discretion will allow the inspectors, for example, to weigh different types of pollution against each other. Regulators do have some discretion in both Sweden and Scotland (but not, as a contrast, in Germany) (Bohne 2001:5). All in all, it seems that we should not exaggerate the difference in enforcement styles between Sweden and Scotland.

5.1.3 Environmental attitudes and behaviour

We shall discuss here the environmental attitudes of people in Scotland and Sweden. This was thought relevant as a potential contributory explanation of any differences in expression of environmental concerns at work in the two countries.

There is data that allows us to compare the attitudes and behaviours of the Swedish and Scottish populations (although in some cases we shall be forced to compare Sweden with the whole of Britain). This said, we are limited in our choice of indicators. We shall here first look at direct measurements of environmental attitudes – revealed preferences, and thereafter study recycling and voting as further indicators of how environmental attitudes are expressed.

5.1.3.1 Revealed preferences

There is a possibility to compare directly the environmental attitudes of people in Sweden and Great Britain[73] using The World Values Survey (WVS 2006), although this data does not distinguish between Scots and other UK peoples.

In surveys carried out in 1999 we can compare the answers from three questions. On all three questions, the Swedish respondents gave more pro-environmental responses. See table 5.4.

Table 5.4 1999 environmental attitudes

	Strongly agree	Agree	Disagree	Strongly disagree	Don't know
"Would give part of my income for the environment"					
Sweden	14.1	50.3	24.6	6.4	4.5
Great Britain	7.1	37.0	35.1	11.2	6.1
"I would agree to an increase in taxes if the extra money was used to prevent environmental pollution"					
Sweden	10.6	56.2	22.3	6.7	4.3
Great Britain	5.8	39.7	34.1	11.5	5.9
"The Government should reduce environmental pollution, but it shouldn't cost me any money"					
Sweden	17.8	36.6	37.7	4.8	3.0
Great Britain	29.0	41.8	19.5	1.7	6.4

Source: WVS data

This dataset also allows us to compare the trends in these two countries between 1990 and 1999. In 1990 the differences between the countries in responses to these three questions were quite small. In both countries we see reduced pro-environmental attitudes during the period. The largest decline can be found in Great Britain. See table 5.5.

[73] For Swedish readers: The smallest nation in the UK – Northern Ireland – is not included in the figures for Great Britain. As the population is small compared to the UK in total, it is unlikely to make any significant difference here.

Table 5.5 Change in environmental attitudes

Difference between 1990 and 1999, %

	Sweden	**Great Britain**
"Would give part of my income for the environment"		
Agree	-14.6	-34.0
Disagree	13.1	25.4
"I would agree to an increase in taxes if the extra money was used to prevent environmental pollution"		
Agree	-8.2	-31.6
Disagree	6.4	23.1
"The Government should reduce environmental pollution, but it shouldn't cost me any money"		
Agree	19.5	28.7
Disagree	-20.3	-35.1

Source: WVS data

Note: "*Agree*" here includes both the original responses "*Strongly agree*" and "*Agree*" etc.

5.1.3.2 As expressed in behaviour

A further question is how these environmental attitudes are expressed in action.[74] An indicator of pro-environmental behaviour in private life that is both available and (somewhat) comparable is that of recycling of household waste.

For Sweden as a whole the last available data is from 1996. The question asked was whether the respondent had decided for environmental reasons to reuse or recycle something during the last 12 months. 90% answered that they had done, and 8.6% that they had not (WVS 2006). A survey from Stockholm, Sweden, provides us with more recent data, although with less geographical coverage. 90% of respondents said

[74] That is, action other than responding to surveys etc. And as we shall discuss later behaviour is shaped in complex ways, and not mere extensions of attitudes.

they often or always recycle newspapers, and almost as many recycle bottles and aluminium cans (with deposit) (SSM 2001:36).

As a comparison, the Scottish Executive (2005c) has published recycling data for Scotland. 61% of households (45% of individuals) reported having recycled something in the past month in 2004 (*ibid*.:33). Newspaper was the most commonly recycled type of waste here as well. 53% of households had recycled newspapers (*ibid*.:33).

It would seem from this data that Swedes are more involved in environmentally motivated recycling behaviour. A caveat is needed here, however, in that behaviour reflects other factors than attitudes. Notably the availability of recycling facilities will have a strong effect on these numbers.

We shall now look at two more public aspects of environmentally motivated behaviour: activism and voting. Firstly, let us look at membership in environmental NGOs. For a comparison we can look at membership in Greenpeace. In table 5.6 we see that both countries have sizeable membership cadres, and that the Swedish membership per capita is close to twice to that of the UK. Unfortunately there is no data available for Scotland specifically.

To fully interpret these numbers one would have to study the bigger landscape of environmental NGOs in each country. For example, the OECD (2002:187) states that the UK has a large number of strong environmental NGOs. There is, however, a lack of publicly available data on membership in many of these organisations.

Also, the range of specific environmental NGOs differs between the two countries. The SNF (Swedish Society for Nature Conservation) is the largest environmental (conservationist) NGO in Sweden, while the RSPB (Royal Society for the Protection of Birds) is probably the largest environmental NGO in the UK, with a similar orientation towards conservation. These organisations are not the same, in the sense of the national Greenpeace organisations being part of the same international organisation, but are perhaps nevertheless similar enough to be comparable. See table 5.6. Swedes are more active here as well, but the difference is smaller.

Table 5.6 Membership in selected environmental NGOs

	Members	% of population
Greenpeace Sweden	App. 65 000	0.72
Greenpeace UK	221 000	0.37
SNF, Sweden	168 000	1.9
RSPB, UK	1 042 000	1.7

Sources: Karlsson with others 2006:1; Greenpeace UK 2006; SNF 2006:54; RSPB 2004:26

Turning now to voting behaviour in parliamentary elections, we can fortunately compare Sweden directly with Scotland. In table 5.7 we see votes for the respective Green Party in recent elections.[75] And in figure 5.3 we see the votes for the European Parliament. Whilst the results for the European Parliament have varied greatly over time, we may say that in the national Parliaments and in recent European Parliament elections the parties are similarly attractive to the voters in the two countries with between 5 and 7% of the votes.

[75] We here face the problem of two different electoral systems though. The Swedish system is a so-called proportional representation (PR) system, where parties get votes in proportion to their percentage of votes (over a threshold of 4%). The Scottish system is a combination of a PR system and a first-past-the-poll system. Each voter here casts two votes, one in a PR system: the regional vote, and one in a first-past-the-poll system: the constituency vote. Some seats in the Scottish Parliament are allocated based on the one vote, the rest of the seats on the other vote.

So, we see that the Scottish Green Party did relatively well in, for example, the 2002 vote with 6.9% of the regional votes. But in the constituency vote they got 0%. It is likely that voters abstained from voting for the Greens in the latter vote since a small party has small chances of getting any seats in a first-past-the-poll system. Overall this translated into 5.4% of the seats. In Sweden, in 2003, the Swedish Green Party got 4.6% of the votes, which resulted in 4.9% of the seats.

Table 5.7 Green Party voting in the latest parliamentary elections

Scotland		1999	2003	
Votes %		3.6 (0) [1]	6.9 (0)	
Seats %		0.8	5.4	

Sweden	1988 [2]	1998	2002	2006
Votes %	5.5	4.5	4.6	5.2
Seats %	5.7	4.6	4.9	5.4

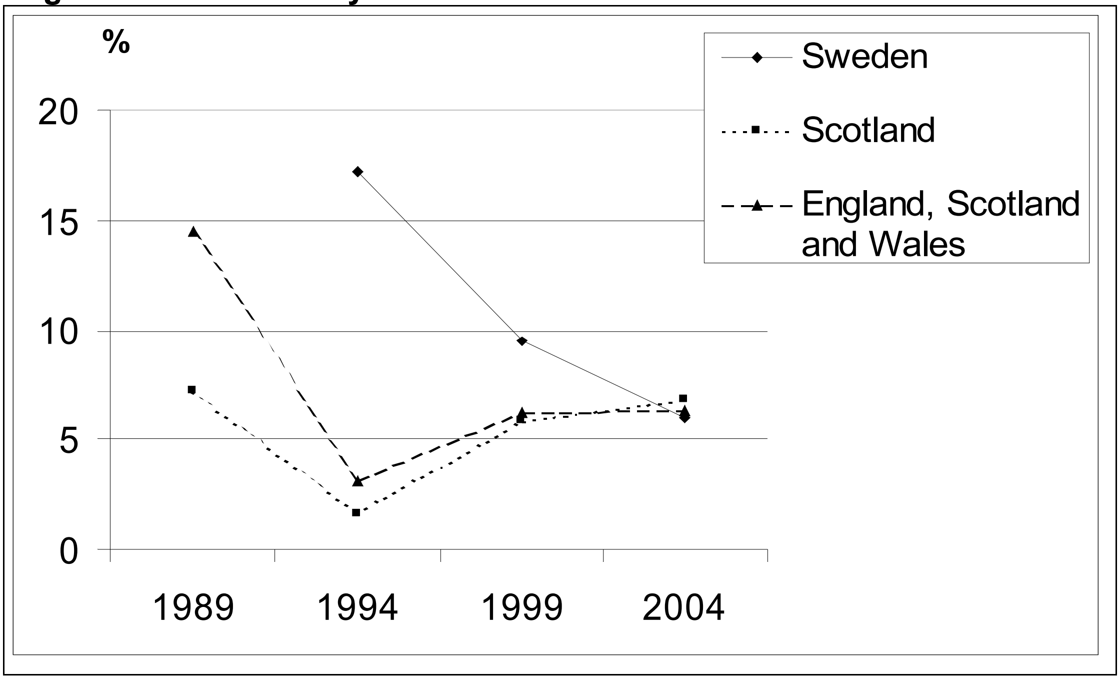
Source: Scottish Parliament 2006; SCB 2006b

Notes:

1) Regional vote (and Constituency vote in parentheses)

2) The breakthrough election of the Swedish Green party, that is the first time they took any seats in the Swedish Parliament, which has 4% cut-off for party representation.

Figure 5.3 Green Party share of votes in EU Parliament elections



Sources: SCB 2007; BBC 2004; Boothroyd 2007, UK Office of the European Parliament 2007

Note: Sweden voted in 1995 rather than in 1994, after its entry into the European Union

5.1.4 Comparing countries

We shall here summarise our comparisons of Scotland/UK and Sweden. Sweden educates more engineers and less scientists than does the UK, which is likely reflected in who does engineering-type work in industry. The UK has a stronger system for protection of the engineering occupation in the labour market, and a system that also appears to give more formal recognition to practical experience. An explanation for this difference may lie in the political economies of the two countries, where in the UK careers are built somewhat more by moves between workplaces. Also, it may be that expertise is marketed and evaluated more informally through inter-firm networks in Sweden.

Environmental staff often have a background in science and engineering. At managerial level, environmental work is most often done part-time and sometimes combined with management of quality or health and safety. Apart from tasks that demand science or engineering skills, environmental staff are also involved in administrative, communication and management work. Increasingly, environmental work is also carried out by other staff, for example engineers.

This interaction between the engineering and environmental areas of education and work is in the UK reflected in a complex, interwoven system of professional institutes in the engineering and environmental areas. In Sweden occupational formation happens primarily through educational attainment, and whereas the engineering education is well institutionalised, environmental education – and environmental engineering education in particular – appear less well established.

Sweden has a history of pioneering environmental policies. Through the harmonizing impact of EU environmental policy, the UK has over the last two decades become more similar to other European countries in terms of environmental regulation. Both countries today have integrated (that is, independent of medium) permitting.

The Swedish organisational structure for the implementation of environmental regulation is fragmented hierarchically and geographically and devolved, as compared to Scotland’s unitary and centralised structure (apart from Scottish Water’s influence on effluents).

The contents of environmental permits are similar in the two countries. One difference is that in Scotland each production process requires a separate permit, whereas in Sweden a permit covers an entire site.

In both countries government collaborates with industry in policy-making, but in neocorporatist Sweden environmental NGOs are more involved than in the UK. Implementation is probably not too dissimilar in the two countries in terms of collaboration versus policing.

It would seem from the data that attitudes among the Swedish public are 'greener', at least during recent years. Recycling of household waste is also more common in Sweden, although that could also be due to the better provision of recycling facilities. Swedes are somewhat more active in environmental NGOs. In terms of voting, Green Party voting levels are quite similar.

Overall, there seems to be a slight difference between the Swedish and the Scots (or British in general where more specific comparison is not possible) in terms of environmental attitudes and behaviour, with Swedes being somewhat 'greener'. Part of this may be because environmental concern has been institutionalised for longer in Sweden, with a longer history, for example, of a Green Party in the national parliament and extensive coverage of recycling facilities.

5.2 Industries: the chemical – dairy comparison

Having discussed the two countries, we shall here discuss the two industrial sectors: the chemical and the dairy industry. For each sector we shall discuss the market structure as an introduction to the sector, and thereafter the technological and environmental dimensions of the sector as they relate to the themes of this thesis. Organisational aspects will be covered mainly in terms of the technological or environmental expertise found in these sectors.

5.2.1 The chemical industry

5.2.1.1 Markets

The chemical industry produces a wide variety of products, including petrol, plastic, pharmaceuticals and detergents to name but a few. This includes household products, but most chemical companies sell to other firms (Cesaroni and Arduini 2001:10).[76]

The chemical sector can be categorised into a range of sub-sectors. A basic distinction is often made between basic (or bulk, or commodity) chemicals produced in large quantities at relatively low costs, and fine (including specialty) chemicals produced in smaller quantities but at higher costs (and prices) (Mol 1995:129).

Exactly what industries count as belonging to the chemical sector varies. Sectors like pharmaceuticals, plastics and oil refineries are sometimes considered part of the chemical sector, but are sometimes excluded. We need to have this somewhat fluid definition in mind when interpreting statistics and other sources on the chemical sector below. For the purposes of this thesis we are mainly concerned about fine and basic chemicals.

The global market is dominated by very large firms, with headquarters in – not least – the US, Germany and France (Key Note 2001:5). Many parts of the sector are struggling to make a profit because of overcapacity (*ibid*.:56), although this varies and pharmaceuticals are among the more profitable sub-sectors as of late.

Sweden has a comparatively small chemical sector (Löfstedt 2003:416). As we can see from table 5.8 nor is the Scottish chemical sector very large. This, however, somewhat underestimates the importance of the chemical sector in the UK. Notably ICI (Imperial Chemicals Industries) had a role as a national flag ship industry, no equivalent of which was ever present in Sweden. ICI was subsequently split into several companies. Today, the UK chemicals industry is dominated by a relatively small number of large, multinational companies (Richards *et al*. 2004:389), some of which have their roots in ICI.

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[76] About half in the UK (CIA 2006).

Table 5.8 Size comparison of chemical sectors

	Sweden	Scotland
Value added / GDP	4%	2%
Plants	916	623
Employees	38 000	25 000

Sources: IVA 2006; Scottish Executive 2005b; the GDP figure used: Scottish Executive 2005b

Notes:

1) The data includes pharmaceuticals as well as rubber and plastic companies. In the case of Scotland refineries are not included.

2) It is not quite clear whether the figure given for Scottish plants is plants or sites. The term used in the statistics is 'units'.

3) Some sub-sectors are made up of large small and medium-sized companies. For example rubber and plastic. This has a 'disproportionate' impact on the figure for number of plants.

This leads us to another difference between the countries. Some of these large chemical companies have their headquarters in the UK (although not in Scotland), for example BP (British Petroleum) and Astra-Zeneca, whereas, virtually all Swedish chemical companies are foreign owned (Löfstedt 2003:416; IVA 2006:38). For example, the gas company AGA was bought in 1999 by the German firm Linde, and Nobel Industries was merged in 1994 with Akzo with its HQ in the Netherlands (PK 2003:5).

This difference in internationalisation can also be illustrated by looking at exports. Approximately 70% of chemicals produced in Sweden are exported (PK 2003:4), as compared to around a quarter of UK chemical production (Key Note 2001:9).

The major chemical sub-sectors in Scotland are: basic chemicals, pharmaceuticals and rubber and plastic (Scottish Executive 2005a). (UK-wide pharmaceuticals dominate, CIA 2006). The Swedish chemical sector is strongly dominated by pharmaceutical companies, contributing 55-60% of the added value, employment and exports of the sector (IVA 2006:38).

The UK chemical sector features some clusters of companies, one of which is located to Grangemouth in Scotland (Key Note 2001:39). This cluster grew up around a port and an oil refinery. A cluster with the same background can be found outside Gothenburg in Sweden. Other concentrations of chemical companies in Sweden can be found close to the largest cities, but also in northern Sweden (PK 2003). An important historical root of chemicals companies in Sweden is production of chemicals for pulp and paper production, typically located in northern Sweden (*ibid*.).

5.2.1.2 Technology

Given that the chemical sector is so heterogeneous, we shall not here try to describe the technology used in any detail. A few general points can be made however.

The chemical industry is capital-intensive, relying on expensive process equipment (although this also varies). This equipment is therefore expected to work and pay itself off over relatively long periods of time, before any renewed investments.

A basic distinction worth noting is that between continuous and batch production. These modes of production have in some ways rather different properties when it comes to environmental performance. For example, a batch process may require cleaning between batches, which is much less frequently needed for a continuous process. Continuous processing is more common for the production of basic chemicals, whereas fine chemicals are more typically produced using batch processing.

A strong driver (as well as obstacle) to investment in the industry is the over-capacity and the ensuing low profitability in many of its sub-sectors. Important rationales for investments have therefore been bottlenecks and rationalisation (IVA 2006:38).

The sector is highly innovative, if measured as the share of companies in the sector carrying out innovation activities (SCB 2006a:42),[77] and more often than in general manufacturing firms the innovations were carried out mainly in-house, indicating a high level of internal engineering capacity (SCB 2006a:46).

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[77] The data includes pharmaceuticals, but not refineries or rubber and plastics. The rubber and plastic industry is also highly innovative, but less so refineries, as measured this way.

The chemical sector is a high technology sector in the sense of having a highly educated workforce. For example, the share of employees holding a PhD in science or engineering is the highest among Swedish manufacturing industries (VINNOVA 2003:48).[78] The share of science or engineering graduates is also very respectable (*ibid*.:48).

Like other manufacturing industries the chemical industry relies on suppliers for all or most of its equipment, and to varying degrees on engineering services. Cesaroni and Arduini (2001) investigated the environmental supply to the (Italian) chemical industry, and came up with some interesting results. Firstly, they found that most of the environmental equipment supply identified was end-of-pipe technology (*ibid*.: 67). They reflect on this that cleaner technology is more difficult to sell as a standardised product (*ibid*.:66).[79] As mentioned in chapter 2, this supports our contention that it is difficult to successfully blackbox cleaner technology.

Secondly, they found that among environmental services offered to chemical companies, advice on cleaner technology was important (*ibid*.:67). This service was supplied mainly from companies in the engineering sector – as opposed to any environmental service companies (*ibid*.:69), which may reflect that what is labelled cleaner technologies may be adopted without any environmental considerations.

5.2.1.3 Environment

Regarding the environmental impact, again, the sector is heterogeneous. Nevertheless, it stands out, of course, compared to other sectors in its high use of many different chemicals, some of which are highly toxic. As mentioned before, this was a reason for it being affected by environmental regulation earlier than most other industries.

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[78] The core chemicals industry has the highest share, even higher than the pharmaceutical industry. Refineries has a medium high share, and rubber and plastics has a low share of science and engineering PhDs.

[79] This comes as little surprise to us given that we have seen that cleaner technology is not a specific set of technologies. It should perhaps have been surprising to Cesaroni and Arduini, however, seeing as they listed cleaner technologies.

A basic environmental concern is that the chemical industry is to a very large extent dependent on oil as a raw material (Key Note 2001:56). This may be difficult to do anything about, although there has been increased interest in recent years in renewable raw materials (IVA 2006:45).[80]

The sheer variety of chemicals used is a problem in itself since it becomes highly onerous to keep track of their use, and to work out what their effects are on the natural environment. The current proposed EU legislation REACH (Registration, Evaluation and Authorisation of Chemicals) targets this problem (EU 2006).

Cesaroni and Arduini have described what they call the "*main trends in the development of cleaner technologies in the chemical industry*" (2001:10). And whilst it is doubtful to label these technologies intrinsically cleaner, they may well offer many firms opportunities for cleaner innovations (although the authors do not explain how they know this); see table 5.9.

The role of public opinion on the chemical industry's environmental performance has been important (Cesaroni and Arduini 2001:15), following not least a series of well-known large accidents like, for example, Seveso. Although local opinion may well matter for individual sites, the main influence of public opinion on firms has been through regulation (PSI 2003:42).

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[80] As part of the green chemistry approach, which puts greater stress on life cycle aspects and resource requirements.

Table 5.9 Technological trends amenable to cleaner innovations

Equipment	Continuous reactors, low temp separation processes, continuous fluid bed processes, safety systems: e.g. control procedures
Chemicals	High-selectivity reactions, reactions producing by-products that can be recycled[1)], biological processes
Products	Water-based inks and varnishes, bio-degradable detergent intermediates, substitutes for CFCs, biodegradable plastics and fibres, substitutes for asbestos

Source: Cesaroni and Arduini 2001:10

Note: The authors did not express this clearly. They might mean recycling of by-products, rather than a choice of particular reactions. But since it is listed under chemicals rather than equipment ('plants'), it seems likely that they mean choosing reactions that allow for recycling of by-products.

The chemical industry, because of its long history of being regulated, has comparatively well-established in-house capacity for environmental work.[81] A recent expression of this is the voluntary Responsible Care initiative of the chemical sector aiming at continuous improvement of health, safety and environmental performance (Responsible Care 2006). The initative started in Canada, but is international, and companies in both Sweden (IVA 2006:39) and the UK (Richards *et al*. 2004:392) are taking part.

Another expression of this is certification to environmental management standards. Most Swedish chemical companies are registered with ISO 14001 or EMAS (IVA 2006:39). Around half of UK chemical companies[82] are registered (CIA 2006).

An indicator of the good in-house capacity for environmental work is given by statistics on environmental expenditure. Statistics Sweden report that around two thirds of environmental expenditure in the sector was spent on internal work (as compared to payments and fees), which is higher than other manufacturing industries (SCB 2005a:12).

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[81] In Scotland/UK and Sweden that is. Likely not to be true in, say, China.

[82] Members of CIA.

Environmental work has undoubtedly been costly to the chemical industry (Key Note 2001:57), but there have also been some economic benefits. Chemical industry firms have been able to sell environmental technology to other firms. Cesaroni and Arduini (2001:40) found a higher ratio of environmental[83] patents in the chemical industry compared to other industries. Examples of such technologies include water treatment chemicals and catalysts for car exhausts (PK 2003).

5.2.2 The dairy industry

We shall here introduce the dairy industry under the same headings as the chemical industry, namely: market structure, technology and environmental aspects.

The main products of the dairy industry are liquid milk, cheese, cream, yoghurt and chilled desserts (Key Note 2003:2). A large part of the unprocessed milk is used for liquid milk, between 40 and 50% in the UK and Sweden (MDC 2004; SDA 2006). To set the scene for the case studies, this section will focus mostly on liquid milk.

5.2.2.1 Markets

Liquid milk is most often seen as a commodity, to a large extent produced and traded in bulk, and market growth is generally slow (Key Note 2003:7), especially compared to some other dairy segments, like yoghurt (*ibid*.:12), and sub-segments like organic milk. Liquid milk competes with other drinks, like fruit juice, soft drinks and bottled water (*ibid*.:57).

The UK and Swedish dairy sectors are in some ways different, and will be described separately below. They share some traits, however. For example, the profitability in the dairy industry is in general low compared to other manufacturing industries (DSCF 2005:50; IVA 2006:66). The industry in both countries has also undergone (and is undergoing) a process of rationalisation (COWI 2000:7; IVA 2006:68-70). After Sweden's entry into the European Union in 1995 it also shared a common

[83] End-of-pipe and recycling technologies.

regulatory framework with regard to the volume of raw milk produced in each country.

The UK

We shall here study the UK rather than just Scotland, since the UK is in many ways one market for milk products. Details about Scotland will be given when possible and relevant.

In the UK, there are several hundred dairy companies, many which are small (Key Note counts 210 local units with less than 10 employees, 2003:126). The sector is polarised between many small operators, and a few very large ones. The three main producers of liquid milk in 2005 were Arla UK, Dairy Crest and Robert Wiseman Dairies (DSCF 2005:50).

Over the last 10-20 years the UK dairy industry has undergone large changes, in terms of consolidation and rationalisation. This has been driven by changes in the supply and sales markets.

The supermarkets have grown considerably during this period and now represent a large share of food retailing. They have also gained a stronger position in milk sales. The distribution of liquid milk used to be mainly through doorstep delivery of bottled milk, but this has increasingly been replaced by sales via the large retail companies' supermarkets (KPMG 2003:25).

This has meant that supermarkets have become the dominant customer of (the large) dairy companies. And as the supermarkets strive to reduce their numbers of suppliers, the dairy companies are now competing for very large contracts with the supermarkets.

Part of the battle between supermarkets and dairies is about control of brands. Approximately 40% of liquid milk is sold under supermarket own-brands (IVA 2006:73), attesting to the relatively strong position of supermarkets in the supply chain.

The cost-focussed competition for the trade of a few retail chains has led the larger dairy companies to invest in larger, more efficient dairy plants (DSCF 2005:50). The investments in new, large plants have in fact led to overcapacity, which has weakened the position of the dairy companies and kept profitability in check (DSCF 2005:50).

Cost competition has also led the trend towards fewer dairy companies through a series of mergers and acquisitions (Key Note 2003:22). In spite of this concentration, the UK dairy industry is, however, still more fragmented than that of many other countries (*ibid*.:67).

Another driver of change in the dairy industry has been the deregulation of the supply of raw milk. The supply of raw milk was first regulated in the 1930s. The Milk Marketing Scheme was administered by regional Milk Marketing Boards (for example the Scottish MMB), and represented a monopoly in the buying and selling of raw milk (DEFRA 2006). The aim was to "*provide for orderly marketing of milk and an organised representation of producer interests to balance that of the dairy companies*" (*ibid*.). The Scheme aimed to keep the prices up, and prioritised the production of liquid milk through an end-use pricing structure (Banks and Marsden 1997:388).

The dairies had under this regime virtually guaranteed (but low) margins, and weak incentives to grow. In fact the pricing structure aimed at a stable return on capital for the processors of 12.5% (Banks and Marsden 1997:388). The processors had little reason to rationalise production.

The market was deregulated in 1994, and the Milk Marketing Board was disbanded (Bates and Pattisson 1997:50).[84] There were several reasons for this, including the

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[84] The mandatory membership for dairy farmers in the MMB was replaced by voluntary membership in regional co-operatives (including Scottish Milk in Scotland and Milk Marque in England and Wales) (MMC 1999:3). Today, approximately 50% of the raw milk is traded via the cooperatives (KPMG 2003:35).

Milk Marque was later split up in three cooperatives, following a report (but no Government ruling) from the Mergers and Acquisitions Commission (DEFRA 2006). Scottish Milk later merged with one of these three to form First Milk (Eclectic 2006).

Now there are 3 groups: First Milk, Dairy Farmers of Britain (former Zenith presumably) and Milk Link (KPMG 2003:35).

concern of dairy companies about prices and the increasing import of milk (DEFRA 2006).

Deregulation exposed the dairy companies to fiercer competition,[85] but also allowed them to consolidate and grow, thus enabling them to meet the challenge from the supermarket chains. The UK dairy processing industry is, however, still more fragmented than comparable markets, as well as less vertically integrated. Less than 5% of production capacity is owned by farmer cooperatives (KPMG 2003:30).

Sweden

There are 14 dairy companies in Sweden (SDA 2006). The industry employs approximately 7 000 people (in 2004) (IVA 2006:66). There are 37 sites producing dairy products, of which 21 produce liquid milk (SDA 2006).

The Swedish dairy industry is strongly dominated by the company Arla, which buys 66% (in 2001) of the raw milk (SDA 2001:25). Arla is followed by Skånemejerier and Milko buying approximately 12% each of the milk (*ibid*.). These three firms (together representing approximately 90% of the milk bought) are all owned by regional farmers' cooperatives (von Unge 2005:5).

The milk supply was de-regulated in 1989, ending a system of price subsidies for the farmers (Sannes 1994). With the entry into the European Union in 1995 came re-regulation of milk supply, in the sense of quotas capping the volume of raw milk produced.

There are no formal monopolies in Sweden on the raw milk or liquid milk markets, but the three cooperatives have refrained from trading in each other's areas,[86] and thus have very strong regional positions both on their supply and sales markets (Sannes 1994), meeting competition only from a few small dairies.

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[85] That the EU milk quota system introduced in 1984 caps the domestic production of raw milk to a level that is below domestic demand has contributed to the competition between dairy companies for milk supply (Banks and Marsden 1997:390).

[86] Until early 2006, at which time a price war started in Sweden.

There is a process of internationalisation going on in the Swedish dairy industry, following from changes to the regulation of export and import in the early 1990s (Sannes 1994), culminating in the Swedish entry into the EU in 1995 (IVA 2006:65). This has increased the import of dairy products, mainly cheese and milk powder (von Unge 2005:5), but also for example yoghurt. Another expression of this internationalisation process is the merger of Arla with a Danish dairy company in 2000 (von Unge 2005:6), and the subsequent purchase of a large UK dairy company.

The Swedish retail market has considerably less power in the milk supply chain than its UK equivalents. This can be seen, for example, from the fact that the rate of own-brand milk sales in Sweden was 14% in 2005, as compared to approximately 40% in the UK (IVA 2006:73).

In spite of recent mergers and collaborations between companies (von Unge 2005), the impression is of the Swedish dairy industry structure thus far being much more stable (and less dynamic) than the UK one. It is also strongly vertically integrated, in contrast with the UK dairy industry.

5.2.2.2 Technology

The dairy industry is capital intensive, using specialised equipment (Key Note 2003:48-49), organised in a basic process according to table 5.10.

Table 5.10 Process steps in liquid milk production

Receipt and filtration/clarification of raw milk
Separation of milk fat (all or part depending on product)
Pasteurisation
Homogenisation (if required)
Deodorisation (if required)
Cooling
Product-specific processing (incl. ageing, culture products and inoculation, churning etc)
Packaging and storage (incl. cold storage)
Distribution

Source: COWI 2000:8-9

Note: Italics specify that this stage is optional, depending on the product produced.

Dairy products can be produced either in batches or using continuous processing (COWI 2007:18). Liquid milk processing is more often continuous than, say, yoghurt production.

This basic process is not undergoing any rapid technological change. COWI (2000:7) reports on current trends in dairy process technology:

- specialised processes, such as ultrafiltration and modern drying processes, for recovery of milk solids,
- more energy efficient processes, and
- electronic control systems, for process efficiency and cost savings.

The most common investment in technology today is in automation (IVA 2006:70).

Although the rate of adoption of new process technology may be comparatively low, the dairy industry is increasingly innovative when it comes to products. Regarding liquid milk, new innovations include for example organic milk (Key Note 2003:3). Other dairy segments – like yoghurt – are, however, more innovative than liquid milk (*ibid*.:12).

The slow change with regard to process technology does not, however, mean a low rate of investments. Investments are being made in larger plants, specialised in a limited range of products (COWI 2000:7; Honkasalo 2003:29) and in automation (IVA 2006:68-70).

There are several drivers behind these developments. Firstly, there is a need for increased efficiency, because of increased (national and international) competition. This is met by rationalisation (Honkasalo 2003:29), specialisation and automation (IVA 2006:68-70). Another driver of automation is the increased demands from retail customers for traceability, because of health and safety concerns (Honkasalo 2003:29; IVA 2006:68-70). Finally, the industry is competing with an increasing range of products, and it is easier to achieve this flexibility in production in a specialised plant (IVA 2006:68-70).

Large plants are now typically automated (Honkasalo 2003:30). There is, however, a large variation within the industry in terms of efficiency (in part due to the difference between new and old equipment, and long investment cycles).

The food sector (data for the dairy sector in specific is lacking) is close to average for manufacturing industries in terms of innovativeness (SCB 2006a:42).[87] The industry is more reliant on co-operation with suppliers for its process innovations than the manufacturing average (SCB 2006a:46), which may reflect the low numbers of graduates among its workforce (VINNOVA 2003:48).

5.2.2.3 Environment

The input of clean water is mainly used for the cleaning of equipment and work areas for hygiene reasons (COWI 2000:7). Effluents rarely contain significant hazardous substances, but their potential environmental impact is reflected in such measures as organic load, pH, nitrogen and phosphorous content and temperature (*ibid*.:7). The rate of loss of milk to effluent varies between plants, but is typically in the 0.5 – 4% range (*ibid*.:18). The effluent often goes to municipal sewage treatment systems, but

[87] In terms of the fraction of companies who innovated in the period 2002-2004.

some on-site wastewater treatment (including neutralisation, sedimentation and/or fat removal) is common (*ibid*.:14, 20).

A major use of energy is the production of steam (often from on-site boilers) used for heat treatment (pasteurisation, sterilising, etc.) (*ibid*.:15), but electricity is also used for machinery, refrigeration, ventilation, lighting and compressed air (drying/evaporation) (*ibid.*:14, 20). Chemicals (detergents, acids, etc.) are mainly used for the cleaning of equipment and work areas (*ibid*.:52).

Apart from effluent treatment, an expression of the environmental work at dairy companies is the introduction of environmental management systems. Certification is underway in both the UK and Sweden (Honkasalo 2003:32-33).

In terms of cleaner production in the dairy industry, COWI (2000:1) stresses that this is as much about how the plant is operated as what technology is used. With regard to technological options, the report mentions the following examples:

Table 5.11 Technological options for cleaner innovations

Environmental aspect	**Technology options**
Water usage and effluents	Continuous processes, automated Cleaning-In-Place systems, the reuse of relatively clean waste waters, the use of pigs and plugs to remove product from pipes, sensors and diverters to separate product from cleaning water
Energy usage	Capture low-grade energy, insulation, more energy efficient equipment
Chemicals usage	Optimisation to avoid over-use

Source: adapted from COWI 2000:24-26.

In general, COWI also promote automated solutions to the control of equipment and processes, although it does note that the increase in automation has also contributed to an increase in electricity consumption (2000:21).

Although the main regulation to affect the dairy industry concerns hygiene requirements (Key Note 2003:31), environmental regulation plays some role. There is, however, a difference here between Sweden and the UK. In the UK dairies were not regulated under the IPC regime (introduced in the early 1990s), and it is not until the last few years under the new IPPC[88] regime that they have been regulated (Honkasalo 2003:27). In Sweden, dairies have been regulated longer than that (at least during the 1990s).

In addition to environmental regulation implemented by environmental authorities, public sector water treatment utilities may also exert some pressure regarding effluents. It is common for dairies, as we have seen above, to be connected to these utilities. In the UK, when there was no IPC regulation in effect, the water treatment utilities had some power to regulate the load from dairies on their treatment plants.

There is unfortunately little information available about environmental competence in the dairy industry in either country. Honkasalo notes, however, a slight difference in attitudes between the UK and Sweden, and reported that some UK dairy interviewees implied that environmental aspects were not very relevant to them. She further noted that Swedish dairies may share this opinion, but here environmental work has been normalised (2003:33). From this we would expect more formalised environmental competence in Swedish dairies.

As compared to the chemical sector in-house environmental competence may be low. Most (approximately three quarters) environmental protection expenditure in the Swedish dairy industry consists of payments and fees as opposed to in-house work (SCB 2005a:12), whereas the chemical sector spends more on in-house work.

5.2.3 Comparing the sectors

We shall here draw together the themes of the section, and compare the two sectors. It is, however, difficult to compare the chemical and the dairy sectors especially since the chemical sector displays considerable internal variation among its many

[88] The main difference between IPPC and the former IPC regime is that IPPC puts a stronger emphasis on pollution prevention as opposed to emission standards (Connelly and Smith 1999:308), but it has also meant the regulation of some industrial processes that were not formerly regulated.

sub-sectors. And particularly in the case of the dairy industry there is also important national variation given the recent de-/re-regulations of national dairy markets.

Nevertheless, the chemical and dairy industries are similar in that they are both process industries, often with low profitability (in general, but this varies with the market segment) and a tendency towards overcapacity (although less pronounced in the Swedish dairy industry).

An important difference is that the dairy industry predominantly produces goods for the consumer market (via the retail sector), whereas the chemical industry sells a majority of its products (but by no means all) to business customers. This gives the retail sector a key role in the dairy market, but less so in the chemical market. In the UK the supermarkets have had a driving role in the restructuring of the dairy industry, but much less so in Sweden.

In both sectors we find a variation between bulk production of commodity products and production of higher value added products in smaller quantities. This variation is more pronounced in the more specialised and varied chemical industry.

The liquid milk segment of the dairy market, which we focus on here, is typically seen as bulk production of commodity goods, and thus compares better to the bulk end of the chemical industry spectrum. They share a low profitability, capital-intensive character.

The dairy industry and the UK chemical industry predominantly produce for domestic markets. Although the UK chemical industry exports only around a quarter of its production, and the UK exports of chemicals are larger than imports (Key Note 2001:7), the industry is more affected by international competition than the dairy industry (especially when compared to the liquid milk segment). The Swedish chemical industry stands out in this respect being largely controlled by foreign owners, and exporting a large share of its production.

The liquid milk dairy industries are strongly orientated to domestic markets, partly because of the limited durability of their products, but also because of recent national level regulation and their history of ownership. Deregulation (due to shifting policy priorities in both countries) have opened up this market to international competition, but this influence has to date been mainly on other segments than liquid milk. In Sweden, the history of strong farmers' cooperatives owning the dairy processing industries appears to have reinforced the domestic focus. Deregulation has increased competition in the UK, but this effect has in Sweden been small because of a gentlemen's agreement between the farmers' cooperatives sustaining near-monopolies.

The chemical industry is technologically diverse and highly innovative with a good in-house engineering capacity. The dairy industry is relatively technologically homogenous, less innovative (especially regarding process technology) and is more dependent on external technological competence. This difference is less pronounced when comparing the dairy industry with bulk chemical production.

Environmentally, the chemical sector stands out, of course, in terms of its use and production of a large variety of chemical substances, some of which are toxic. The sector is also highly dependent on oil as a raw material. In contrast, the dairy industry uses little chemicals, apart from some amounts for the purpose of equipment cleaning, and the raw material is milk (although it takes a certain amount of energy input to produce milk). The main environmental impact of dairy processing is the organic content and the pH of the effluent. The dairy industry often relies on public sector effluent treatment works to manage its effluents, whereas the chemical industry is often forced to treat its own effluents.

The chemical industry has a longer history of experiencing relatively strong pressures from environmental regulation, and has, it seems, a better in-house capacity for environmental work.

6 Chemicals industry cases

We shall here present the two chemicals industry case studies. First the Swedish case and then the Scottish one.

The Chemicals Sweden case is the one with the highest environmental ambitions out of the four case studies, and gives us a good example of what appears to be intentional cleaner technology. It also includes an interesting, open conflict about the treatment of ventilation gases. Chemicals Scotland stands out in terms of well-established expertise, networks and routines for dealing with the environmental aspects of technology.

6.1 Case study: Chemicals Sweden

This case study is divided in four parts. The first part gives a background to the study. The second part introduces the project studied. The third part describes some of the main decision points in the project and the differing opinions with relation to those decisions. The fourth and last part will discuss some themes from the case.

6.1.1 Background

This section will give the background to the case study, in terms of the company, the site, and their organisations. Special attention will be given to the engineering capacity and to environmental aspects of the site.

6.1.1.1 The company

The company produces healthcare products, coatings and chemicals. Sales in 2001 were approximately EURO 14 billion, and the company had approximately 66 000 employees in 80 countries, 62% of the employees are employed in Europe.[89] Company headquarters are located in the Netherlands.[90]

The project under study was an expansion project, called EMU 2000, partially driven by environmental concerns, at the Emulgol plant on the West coast of Sweden. The company bought this plant in the early 90s.

The chemicals part of the company is organised into a number of business units, two of which are represented with production units on the site: Surface Chemistry and Functionals.[91] Within Surface Chemistry there is a sub-unit called Surfactants Europe, which includes the Emulgol plant we are studying here.

Within Surface Chemistry there is also a division called Service Unit Sweden dealing with IT, economy, environment and facilities. The Service Unit is represented on the site. The Site Service Unit also includes an R&D department, which is however focussed on products rather than process technologies, and it had no role in this project.

Financially Surfactants is doing less well than other parts of the business.[92] Surfactants is however an expansion area, which means investments and expansion of production facilities and investments in product related R&D.

6.1.1.2 The site

The site produces fine chemistry products in four plants. Production is organised into two production units: Production Surfactants and Production Ethylene Amide, each

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[89] Printed slides provided by the researcher (see Appendix A).

[90] We shall here call the company Chemicals Sweden, indicating the location of the site rather than its ownership.

[91] This section and the next describe the current organisation. When relevant for the analysis differences between the current organisation and the organisation at the time of the project will be described.

[92] HSE manager

of which has two plants on the site.[93] The project studied concerned the Emulgol plant, which is one of the plants of Production Surfactants. The managers of the production units report to the site manager as well as to the business unit Manufacturing Manager.

The Emulgol plant produces surface chemistry products. The production process is complex in the sense that the plant produces approximately 150 products, based on approximately 100 different inputs.[94] The main input is ethylene oxide, produced on site in another plant. The production is based on batch technology, and organised in several main steps: catalysis, reaction and after treatment. The plant runs in four parallel lines. Thereafter the product is sent to storage.

Production Surfactants employs close to 70 people, almost half of which are operators in the two plants.[95] There are also employees working on Logistics, Process and Quality Control (PQC),[96] Maintenance and HSE[97] (one employee).

The PQC unit employs a few process technology engineers. At the time of the project this function was part of the Site Service Unit. The process engineers and the maintenance engineers constitute the engineering capacity at the site.

6.1.1.3 The environment

The environmental aspects of the plant's production that are most relevant to this study are emissions to water and air.[98] Water is among other things used to clean the

[93] Safety engineer

[94] Project leader, consultant.

[95] Safety engineer

[96] The process engineer, who is now employed at the new PQC group at the production unit, was at the start of the project employed in a process engineering group within Service Unit Sweden (SUS).

[97] Health, Safety and Environment

[98] Consumption of water was also an issue, but closely aligned with the production of effluents. Energy consumption was not a main environmental issue.

process equipment after running a batch. The waterborne waste is either burnt[99] in an incineration oven or released into the sea. The exhaust fumes from the oven are scrubbed. There is a wet stream from the scrubber that is released into the sea. The oven (and scrubber) is a common utility for the four plants at the site, and operated by one of the other plants. Some of the gaseous emissions, the so-called 'ventilation gases', or 'vent gases' for short, are also scrubbed. The remaining gases are released directly to the air.

There are also safety and health aspects of the plant activities. Not least ethylene oxide – the main input – is highly explosive and needs to be tightly controlled.

The site is operating under a licence granted by the Environmental Court, and environmental inspections are carried out by the Municipality as well as the County Administration.[100]

The Site Service Unit is among other things responsible for production-related HSE issues. The HSE department staff work as experts in the fields of health, security and the environment. They are responsible for production-related regulatory affairs, and provide expertise when called upon by the production organisation.[101] There is also, as mentioned above, an HSE co-ordinator employed at Production Surfactants.

The interviewees in the case study are mainly from Production Surfactants and from the HSE department in the Site Service Unit.

6.1.2 The project

This section introduces the project studied. Firstly, by setting out the scope of the project. Secondly, by describing the main motives behind the project. Lastly, the way the project was organised is presented.

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[99] When the water content of the waste stream is too high it does not burn, therefore other fuel is added.

[100] Länsstyrelsen och kommunen.

[101] HSE manager

6.1.2.1 Scope

The wish to expand the plant existed at least as early as 1992.[102] In 1994/1995 a feasibility study and a further planning project were performed. The planning project came up with a detailed budget of 350 million SEK.[103] The finally approved project had a budget of approximately 245 million SEK.[104] The project started in 1996 and ended early 1999.

An important technological part of the project was about restructuring the process routes. Instead of a complex - but flexible - 'nest' of routes, the project created four separate routes, each with catalysis vessel, reactor etc. The systems for feeding substances into and out of the process were completely changed. The project introduced 'pigging'[105] technology for propulsion, a system that uses plugs that are propelled through the pipes, and a new recipe-based control system. The drum filling facility[106] was rebuilt, replacing two smaller facilities. Another part of the project aimed at finding a new way to deal with gaseous emissions. Some other parts of the project also concerned technological change, but are less relevant for this case study.

As part of the ambition to expand the plant, a new environmental licence had to be applied for. The application was filed in 1994.[107] The new licence stipulated emission limits, but also contained conditions requiring that the company investigate several things. The investigations concerned both new measurements of gaseous emissions and investigations into potential technological solutions to manage the emissions and effluents. This work ran in parallel to the expansion project, but also linked in with the project. This will be described in more detail later.

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[102] Environmental engineer

[103] Swedish Krona. Approximately £25m

[104] Approximately £18m.

[105] Pluggskjutning

[106] Fathallen

[107] Environmental engineer

6.1.2.2 Motives

The project had a background in concerns for profitability as well as environment and safety. The existing plant was badly adapted to the current operations, after extensive changes in the range of products since its construction in the 1970s, and therefore needed to be modernised.[108] As part of the overall company strategy to expand production in the area of surfactants, it was decided to invest in an expansion project at the Emulgol plant.

Maintenance of the plant had also been neglected for a number of years, leading to a relatively high frequency of accidents and relatively high levels of emissions.[109] The company had in fact been sued in 1992 for a chemicals release.[110] In 1994 the company applied for a new environmental permit for all the plants of the site, also triggered by a wish to increase the capacity of the plants in the near future. The permit stipulated, among other things, new emission limits. The new permit was a pre-requisite for the project and partly shaped its content. Improved environmental and safety performance was one of the core aims of the project.[111]

The plant manager claims that the project was initiated purely for environmental reasons.[112] The environmental problems and the environmental permit were indeed important reasons for initiating the project. But the permit itself was also motivated by a wish to increase capacity. It is also clear that increased capacity was part of the vision developed in the planning project.[113] In addition to the HSE aspects and the need to increase capacity, the project also aimed at improved cost-efficiency, productivity and quality,[114] reflecting concerns for competitiveness and profitability.

[108] Plant manager

[109] Plant manager

[110] Plant manager

[111] Plant manager

[112] Plant manager

[113] Plant manager

[114] Plant manager

The technological strategy chosen included automation and reduced manual handling, thus potentially increasing also labour productivity. Later, a reduction of the workforce was implemented. Whether this was an intended outcome was contested, as will be described later.

The plan to increase capacity rested on the making of market forecasts. Thereafter, the project plan, produced by the plant, was negotiated with the business unit manager, and all the way up to the Supervisory Board of the concern. The plans were more or less unchanged in this process, apart from the market forecasts that were lowered.[115] The goal of increased capacity was however kept.

The group working with the planning project, led by the plant manager, first came up with a draft plan that would have cost 350 million SEK,[116] and they judged that they would never get that much money, and decided to reduce the project budget by 100 million SEK.[117] This required priorities to be made, and some ideas for improvement were excluded.

According to the plant manager the exclusions affected neither the HSE goals nor the capacity goal. Instead it was the productivity goal that had to give, through the exclusion of some of the automation measures and some simplification of handling.

However, one of the most costly things that was excluded was the nitrogen ballast for the many tanks in the plant. The main function of the ballast would have been to reduce the risk of explosion of the main chemical: ethylene oxide. The nitrogen ballast would also have reduced the efficiency of the production, and higher levels of management expressed doubts about the technology for this reason,[118] which may have contributed to the technology not being introduced in spite of its contribution to safety.

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115 Plant manager

116 Approximately £25m.

117 Approximately £7m.

118 Process engineer

6.1.2.3 The project organisation

The project was led by a project leader reporting to an internal customer: the plant manager, supported by a steering group. There were approximately 30 people working full time in the project, organised in groups according to area of competence, and led by group leaders.[119] The project was divided into eight sub-projects, each led by a sub-project leader. Each sub-project drew on competence from the groups, so that the project was organised in a matrix.

The competence in the project comprised areas like: facility construction, steel construction, mechanics, electricity, instruments, process control and process engineering. One administrator worked full time on an administrative sub-project.

The core staff consisted mainly of temporarily hired staff from consultancy firms, including the project leader. A few permanent Chemicals Sweden employees worked full time on the project.[120]

There was no environmental expert working full time on the project, but staff from the HSE department monitored the project with regard to HSE aspects and took part in project meetings, as well as contributed extensively in parts of the project with, for example, risk assessments.[121] The environmental monitoring work in the project was carried out by an environmental engineer in the HSE department, and mainly concerned issues relating to the environmental permit. The environmental engineer testified that, in general, referring to licence conditions helped in convincing others about the importance of environmental measures. It was part of the project management policy to have someone from HSE in this role.

This absence of full time environmental project workers mirrors the internal consultant role[122] of the HSE employees. A problem with this, according to some of the HSE staff, is that they do not automatically get information until their services

[119] Project leader, consultant

[120] Maintenance manager

[121] Safety engineer

[122] They are not consultants in the sense of an internal market for their services, but in the sense of being called upon to contribute on someone else's initiative.

are asked for. Another member of the HSE staff said that this was not so much of a problem, as nothing stops them from seeking out the information if they so wish.

HSE staff are typically not involved in the early stages of a project.[123] The HSE manager was in this case involved in the planning stage of this project, but only informally. This contrasts with the parallel work that was primarily motivated by the environmental permit, where environmental staff had key roles.

6.1.3 Decision points

This section will describe some of the main decisions made in the project relating to the technological and environmental aspects of the project. Some of the decisions were controversial,[124] and the different standpoints will be described, including who held which standpoint.

6.1.3.1 The pigging technology

The main environmental improvement in the project was gained through the introduction of a pigging system.[125] The main function of the pigging system is for cleaning pipes after a chemical has been fed through them. Previously this was done by washing the pipes with water, producing large amounts of effluent, which had to be burnt in an incineration oven.

Some alternatives to the pigging system were considered, namely: reducing the lengths of pipe, thus reducing the volume of washing water; rearranging the tank storage facility[126] (presumably making it less complex and messy, and so reducing

[123] HSE manager

[124] Controversy here refers to issues where different interviewees have different opinions, whether this has caused open conflict or not.

[125] Project leader, consultant

[126]Tanklagret

pipe lengths); and introducing campaigns, that is, processing similar products in sequence which would reduce the need to wash the pipes between batches.[127]

Reducing the amount of effluent from the plant was one of the goals of the project.[128] It was motivated not least by the environmental permit. As mentioned above, the environmental permit triggered other projects running in parallel with the EMU 2000 project, aiming at treating the gaseous emissions and the effluents. This included an idea to build a new, larger incineration oven to burn some effluents and gaseous emissions. The oven previously used to burn effluents was at the time running at close to full capacity,[129] and any excess water would have had to be transported for external destruction. Reducing the amount of effluent reduced the urgency to build a new oven,[130] which would have been costly. Burning effluent with high water content is also quite expensive because of the need for added fuel.

There was also a plan for a new effluent treatment facility, based on, firstly, concentration of the effluent by evaporation and, secondly, purification with membrane technology.[131] However, the reduced volume of effluent achieved with the pigging system reduced the need for this treatment facility, and to an agreement with the regulator to abandon it.[132] The pigging system thus allowed the company to improve environmental performance, whilst at the same time avoid or delay costly end-of-pipe investments and the, also costly, shipping of effluent for external destruction.

The pigging system also brought other advantages. The work environment was greatly improved,[133] since the washing procedure was largely manual and quite messy work, and some of the chemicals handled dangerous. As less chemicals were

[127] Project leader, consultant

[128] Project leader, consultant

[129] Environmental engineer

[130] Process engineer

[131] Environmental coordinator

[132] Environmental coordinator

[133] Project leader, consultant

lost to washing water with the pigging system, there were also resource efficiency gains. The efficient cleaning with the pigging system also meant less contamination of products, that is, better product quality.[134]

The pigging system also opened up opportunities for automation. The pigging system can also be used to feed chemicals through pipes. The pigging system was implemented for the feeding of raw material into the process and for feeding the products out of it. A new control system[135] was introduced for the feeding in of raw materials and for the feeding out of products. The pigging system made the introduction of the new control system possible. The new control system also increased product quality by standardising operating routines.

6.1.3.2 How to deal with the vent gases?

A complex, part of the project was about dealing with the gaseous emissions, the so-called vent gases. The vent gas sub-project was driven by the environmental permit from 1994, which stipulated that something should be done to further purify the vent gases from the site.[136] One of the chemical compounds in the vent gases was ethylene oxide, for which there was a separate condition in the environmental permit. The vent gas condition was not specified for the Emulgol plant, but for the total site. The plant, however, represents one of the major sources of ethylene oxide emissions at the site.

The treatment of the vent gases was contested on several occasions. The company contested the inclusion of the vent gases in the permit in the negotiations with the environmental authorities in the early 90s. According to the environmental engineer it was seen as too costly by plant management. Later, during the planning project when the project budget had to be reduced, the vent gas treatment was raised as a possible exclusion.

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[134] Maintenance manager

[135] Alternatively called ‘recipe control’ (receptstyrning) or ‘batch control’ (batchstyrning).

[136] Project leader, consultant

Since there was no permit condition specifically for this plant, the vent gas treatment could have been managed in a separate project, like the new oven and the effluent treatment. It was however included as part of the EMU 2000 project. There were several reasons for this. One reason was the idea that there might be possibilities to deal with the emissions at source and reduce the need for such end-of-pipe treatment.

Another reason was the commitment of the plant manager. She had a track record of leading projects with an environmental profile. Starting as an engineer, her career had benefited from doing environmental work, especially when the environment was "*a hot topic in the company*".[137] She here contributed to the decision to include the vent gas treatment.

Different technological alternatives for dealing with the vent gases were looked into, and abandoned. Firstly an idea involving a separate incineration oven for the Emulgol plant using catalytic combustion was investigated.[138] After some work on this news came from the US Occupational Safety and Health Administration that such facilities in the US had been exploding. Risk assessment showed that this solution would be too risky. After that an idea about a (re-active, acid-basic) scrubber was developed. But this idea was also abandoned, partly because it generated waste that would have had to be incinerated.

There also arose some uncertainty as to how serious the gaseous emissions from the Emulgol plant actually were. The need to do anything and the continued relevance of a measurement of them from 1992-1993 were questioned.

The plant management argued that the emissions were actually not serious enough. This resulted in a dispute over a suggestion for new measurements of the emissions. The Chemicals Sweden employed process engineer and others argued that the old measurements were not reliable. The plant management, on the other hand, argued that the existing data were sufficient, since nothing had changed in the production.[139]

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[137] Plant Manager

[138] Safety engineer

[139] Environmental coordinator

The project leader claimed that the emissions were very small, supported by the HSE manager who argued that they were not that serious.

It may have been a contributing factor to this dispute that the vent gas emissions are difficult to measure for several reasons.[140] The emissions are very uneven due to their origin in a batch process, and measurements need to be made over a period of time. They are also in part made up of surfactants, prone to clogging up measurement instruments and to creating foam. The gaseous emissions also have a high steam content, which further complicates measurement. The measurements that were later made took two years to do.

An added uncertainty came from the reconstruction of the plant potentially changing the emissions. The vent gas treatment sub-project was scheduled at a late stage within the EMU 2000 project, so as to be able to judge the future emissions from the plant as accurately as possible.[141] On the other hand, this meant that there was little time to do any new measurements of the gases. The lack of time to do new measurements was one of the arguments used against doing new measurements. In the end no measurements were made as part of the project.

It was also a matter of money. According to the HSE manager the vent gas sub-project was crowded out budget-wise, by a focus on the core manufacturing process. The overall money spent in the EMU 2000 project very nearly equalled the budget allocated to it. This means that the money for the vent gas treatment was spent on other things, which supports the crowding out argument.

By this time, there were also plans in place for the new incineration oven, which would burn not only some of the effluents, but also, it was suggested, the gaseous emissions from all the plants on the site. The vent gas treatment work in EMU 2000 was eventually abandoned, and the responsibility for the problem was transferred to the new site oven project.

[140] Safety engineer; HSE manager; Environmental coordinator

[141] Process engineer

It is also interesting to note that by this time there was a new plant manager cum internal project customer in place. The original plant manager, who had championed the inclusion of the vent gases into the project, had by now been promoted to another position.

The new site oven was built after the project in 2003,[142] and there were then also plans to build a pilot facility based on the previously abandoned acid-basic scrubber technology. A renewed condition in the environmental permit from 2001 stipulated that measurements of the vent gases were to be made.[143] Apparently, the company failed to convince the regulator that the vent gases were not a problem. New measurements were made after the project.

The dispute about money also survived the end of the project. As the vent gas sub-project was cancelled, so was the part of the budget dedicated to this work. Some people, notably the HSE department environmental engineer, argue that the funds should have been made available for the further work needed to investigate the issue, but that did not happen. The current plant manager explains that when a project is over, it's over, and the money is gone:

> *Since this sub-project had progressed so far – and then of course you make sure that you've got money, that you have a budget and all that – and was then shut down, you can interpret this as if the money that we kept such a close eye on and actually had received the confirmation that we'd get, that it actually was still in some wallet somewhere. But that's not how it works in real life; when you shut a project down, it's shut down.*

6.1.3.3 Implementation and rationalisation

In 1999 the formal project ended, but a lot of implementation work remained. Some parts of the project were implemented, for example the new catalysis vessels and the new drum filling facility, but lacked formal instructions and routines. Others were in

[142] The Emulgol plant oven would have burnt gases either from only the Emulgol plant, or combined with gases from another plant to even out the gas flow from the batch production of the Emulgol plant. There is now a separate incineration oven being built on another plant, the gases from which were once intended to be mixed with the gases from the Emulgol plant.

[143] Environmental coordinator

place, but did not yet work very well, for example the pigging system.[144] And some parts were barely in place, such as the batch control system, the implementation of which was run as a new project.

The project had met its budget very well, although work remained on some sub-projects, and it was decided that it was to end as planned. Apart from the remaining implementation work and bugs, there was also a learning period for the operators. Not least the new control system, once up and running, required radically new ways of working. For these reasons there was somewhat of a bottleneck in terms of knowledge about the new system and its implementation.[145]

The project was approved partly on the basis of forecasts of future market developments, indicating a need for an increased capacity. The forecasts turned out to have been too optimistic, and when the project was over there was no need for any increased capacity.[146]

In mid 1999, that is, soon after the project ended, the news came about a major rationalisation of the plant. Profitability was too low and there was no demand for the planned increased capacity. So to reduce costs Chemicals Sweden laid off close to half the workers in the plant.[147] This of course lowered their motivation, and with the reduced number of workers, the bottleneck was a fact. Implementation slowed down considerably.

The rationalisation created a conflict between the workers and the employer, and the union organised the workers' resistance to the rationalisation. The outcome of the conflict was that a plan for a system with three shifts was abandoned, and that between 40 and 50% of the workers were laid off.[148]

[144] Process engineer

[145] Operator

[146] Plant manager

[147] Project leader, consultant

[148] Operator

It is a matter of contention whether the rationalisation can be said to be a direct and intended result of the project or not. But the technological changes introduced facilitated the reduction of employees.

6.1.4 Discussion

Looking at the plant after the project was over, and after subsequent implementation work, the project could be deemed quite successful in relation to its aims. The environmental performance was better, the work environment was cleaner and safer and the quality of the products was higher. In terms of technology, the batch control system had been implemented, and the pigging system was working with considerably less problems, contributing to improved resource efficiency. Table 6.1 lists the main technological decisions studied.

After improving the work organisation the capacity had been increased, and as the number of workers had decreased labour productivity had been raised.[149] Profitability was still low however, and in 2003 there were plans to lay off also white-collar staff.

This case shows an example of what appears to be an ideal-type win-win solution. Environmental performance was a part of the core aims of the investment, together with resource efficiency, capacity etc. The pigging technology solution improved both the environmental and economic performance of the plant, and so deserves the label cleaner technology.

Furthermore, the pigging technology also helped avoid, reduce or delay other end-of-pipe investments, and was in this sense an alternative solution to environmental problems. The pigging solution did not, however, solve the environmental problems completely and there was still a need for end-of-pipe measures.

All the end-of-pipe investments made were done in separate projects. In part this reflects the site having joint utilities for all the plants, but it was also in part an

[149] Maintenance had been outsourced, which, according to the shop steward, was a technical trick to increase productivity as it appears in the books.

outcome of the controversy about the vent gases. This controversy shows how the company had little wish to go beyond the win-win scenarios, but resisted investment that would improve environmental but not economic performance.

Table 6.1 Decision points Chemicals Sweden

Decision points	Arguments for	and against
project	*capacity, reg., Q, cost eff., productivity*	
core technology		
heat exchange	cost eff.	
pigging	reg., RE, Q	H&S
- rearrange storage facility (no)	reg., RE	
- campaigns (no)	reg., RE	
- oven & ETP (no)	reg.	cost
nitrogen ballast (no)	H&S, reg.	cost, prod. econ.
end-of-pipe technology		
vent gas treatment (no)	reg.	cost, T
- separate oven (no)	reg.	cost, risk
- scrubber (no)	reg.	cost, E
outside project		
several other projects, incl. hardening of surfaces, new drains, new roofs, scrubbing and sending more waste to treatment company	reg.	

Notes: 1) Abbreviations used: reg. = regulation, E = environmental, RE = resource efficiency, H&S = health and safety, T = technical difficulties, Q = quality, eff. = efficiency, prod. econ. = production economy.

2) Items proceeded with a '-' means that they were alternative solutions to the next item above without a '-'. Items follow by '(no)' means that this option was not chosen.

The company had a rather weak internal engineering function, and had to rely on consultants for a lot of the design work. There was however a fairly strong internal environmental organisation, with environmental staff both in a separate department and at the plant. The role of environmental staff in the project was limited to monitoring the project in terms of regulatory compliance, and coordinating the project with the permit driven end-of-pipe projects running in parallel.

The environmental staff appear to have had a relatively limited influence in the project. Their input at the planning stage was marginal. During the project their main influence was based on the environmental permit, but as we saw from the vent gas controversy, even these permit conditions could be questioned. In spite of an alliance with some of the in-house engineers they failed to save the vent gas treatment.

In contrast, the plant manager in the internal customer role appears to have been able to champion environmental performance. It was in part down to her that the vent gas treatment was initially included in the project initially. It is interesting that it was subsequently excluded after she had been promoted to another position.

6.2 Case study: Chemicals Scotland

As mentioned in chapter 4 the fieldwork for this case study was aborted after a misunderstanding. This means that the resulting case study is somewhat less detailed, but there are still interesting results to discuss.

6.2.1 Background

This section will give the background to the case study, in terms of the company, the site, and their organisations. Special attention will be given to the engineering capacity and to environmental aspects of the site.

6.2.1.1 The company

Chemicals Scotland has its origin in a large UK chemicals group. The company was part of the chemicals and pharmaceuticals business that was subsequently spun off. In a second spin off deal in 1999 Chemicals Scotland was formed and bought by two investment companies.[150] The head quarters are now in Manchester, where the main R&D centre is also located.[151] There are four manufacturing sites, three in England and one in Scotland.

Chemicals Scotland produces fine chemicals. The company is organised in business ‘sectors’ corresponding to different product markets (and sub-divided into business ‘units’ relating to market segments).[152] The business sectors include agrochemicals, fine chemicals, biotechnology and pharmaceuticals. The business units commission production from the manufacturing units and control their investments.[153] A particular manufacturing unit may produce for one or several business units.

6.2.1.2 The site

The Scottish site produces among other things fluoroaromatics for agrochemicals, inks and dyes.[154] Over the last ten years the product range has shifted from dyes towards inputs for biotech and pharmaceuticals. Apart from its own products, Chemicals Scotland also sells manufacturing capacity.

At the Scottish site there is, apart from the manufacturing organisation, among other things also an analytical department and a process technology (PT) department. The PT department, staffed by engineers and scientists, develops and scales up production processes for new products, commissions new equipment, and helps with trouble shooting in manufacturing.[155] The analytical department does environmental and other chemical analyses. There are approximately 800 employees at the site in total.[156]

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150 Process engineer - project leader

151 Technical director

152 The company was unfortunately not willing to provide a proper organisation chart.

153 There is some leeway for the site, in that it decides on how some overhead costs are charged.

154 Technical director

155 Environmental technology consultant

156 Approximately 150 people were laid off in 2003.

Product ideas typically derive from the R&D centre in Manchester, apart from the biotech and pharmaceuticals areas, in which the company has no products of its own, and does only contract manufacturing. The PT department is thereafter responsible for the scaling up of processes for manufacturing. Development projects are organised in commercial project teams, consisting primarily of staff from PT, manufacturing and business units.[157]

6.2.1.3 The environment

There is a range of products produced at the site, with differing environmental profiles. Several of the chemicals handled are toxic. Some are explosive and/or volatile. The existing system for handling emissions and effluents includes scrubbers and an effluent treatment plant (ETP).[158] The final effluents are released into a large estuary.

The site is regulated by SEPA under the IPC legislation. There is one environmental permit per production process including the utilities. The pressure from the regulator had decreased over recent years:

> *A lot of the experimental and development work we used to get involved in, in testing, has gone down dramatically. And I suspect that the reason why it… dare I say, I don't think there's as much pressure from SEPA these days.*[159]

The company is not certified according to ISO 14001, but has an environmental management system. As part of this system, environmental performance contributes to how salaries are set for the operations managers (who represent the business units at the site).[160]

The environmental aspects of process development projects are worked through according to a methodology called 'PTD-SHE studies' (Process Technology

[157] Environmental technology consultant

[158] Technical director

[159] Technical director. Another reason why the amount of testing has gone down is a changed monitoring regime – a change driven by the regulator.

[160] Technical director

Development – Safety, Health and Environment studies). The methodology encompasses both the product and the production process. Its origins lie in methodologies for environmental assessments and safety assessments, which have been integrated by the Environmental Technology Consultant (see below).[161]

The PTD-SHE methodology prescribes a series of studies to be carried out during the course of a development project, from the lab stage to a review after the process has been operating for some time.[162] The individual studies involve different members of staff depending on the focus of the particular study. The results of the studies include an environmental impact assessment and an occupational health statement. See table 6.2.

There are several environmental experts at the site. There is a Site Environmental Advisor managing permits and contacts with the regulator. There is also a corporate (internal) consultant specialising in environmental technology based in the local PT department. Furthermore, there are three Advisors on environment, safety and occupational hygiene respectively at corporate level who may get involved in projects at the site.

The Site Environmental Advisor's role deserves further comment. He admitted to not having any environmental qualifications, and had got his job through having good contacts with the regulator, from having been involved in previous work on setting up the ETP. He was at the time a manager in the manufacturing organisation.

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[161] In spite of this formal integration it was called 'SHE studies' or 'Hazards studies' depending on the interviewee and his/her particular perspective.

[162] The starting point of the methodology is adapted to particular projects depending on what stage of development the product and the associated production technology is when the project begins.

Table 6.2 PTD-SHE studies[163]

<table>
<tr><th>Study no</th><th colspan="2">Description</th></tr>
<tr><td>0</td><td colspan="2">At the lab stage; about what chemical reaction routes to choose</td></tr>
<tr><td>1</td><td>A preliminary risk assessment</td><td rowspan="2">About the raw materials and the chemical process</td></tr>
<tr><td>2</td><td>Identifying major hazards</td></tr>
<tr><td>3</td><td colspan="2">About the production process equipment
(at this stage there are engineering line diagrams available)</td></tr>
<tr><td>4</td><td colspan="2">After the production process is built</td></tr>
<tr><td>5</td><td colspan="2">A review some time later</td></tr>
</table>

The analytical department also includes a laboratory, which among other things does environmental monitoring and analyses, and is responsible for the effluent treatment plant. The company also buys environmental (and other) analytical services from a lab in England owned by its former parent company.[164]

There is a well-developed, informal network between the Technical Director,[165] the Environmental Technology Consultant, the site Environmental Advisor and the corporate Environmental Advisor. Several of these have a long history of working with environmental aspects of technology in the company. Current issues are discussed in the network on a daily basis:

> *And generally sort of share half a dozen e-mails a day, and things like that. Even though we're in different departments and different locations on the site.*[166]

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[163] The accounts of the PTD-SHE studies vary somewhat between interviewees, and this description is a compromise between these accounts. The table gives a good overview of the types of activities involved though.

[164] Technical director

[165] Full title: Technical, Development and Environmental Manager.

[166] Environmental Technology Consultant.

The overall impression is of an ambitious environmental organisation, and well-developed routines for dealing with the environmental aspects of technology, supported by a long-standing informal network. This ambitious environmental organisation was set up when the company was part of the large UK chemicals group.[167] And in spite of the current environmental ambition level being somewhat lower under the new owners and because of a difficult financial situation,[168] as well as the reduced environmental pressure from the Scottish environmental regulator, the (formal and informal) environmental organisation had remained intact.

6.2.2 The project

This section introduces the project studied. Firstly, by setting out the scope of the project and the main motives behind the project. Secondly, the way the project was organised is presented.

6.2.2.1 Scope and motive

The project concerned contract manufacturing of an intermediate for a fungicide at a volume of 600 tons per annum. The deal was made in 1999/2000. The customer contracted out initial volumes to two competing manufacturers, with the aim of later producing some of the substance in-house and selecting only one of the two suppliers for continued production.[169] The customer provided the basic chemical process, and supplies the raw material.

Chemicals Scotland had not produced this product before. The basic motive for the company was to acquire this new line of business.

[167] Technical director

[168] Process engineer - project leader

[169] Process engineer - project leader

The chemical process provided by the customer was not optimised. This was left to the contractors. The initial budget was £7.0m, but had to be reduced to £4.4m to meet the financial limits set by the Board. The project eventually ended up at £5.8m.[170]

Chemicals Scotland was able to design the process into an existing plant at the site with excess capacity, which helped in keeping investment costs down. The process was also designed and planned for a somewhat smaller initial capacity, later to be increased up to 600 tons by further process optimisation.[171] Another strategy to keep costs down was to opt for continuous processing for parts of the process, which reduced costs but created logistical difficulties to be overcome by buffering of the fluids.[172]

Environmental performance was not a core motive for Chemicals Scotland. However, the project completed the PTD SHE studies according to the company norm.[173] The company also had to get a new environmental permit for the new production process.

6.2.2.2 Project organisation

The internal customer of the project was from one of the business units in the Agrochemicals Sector (division) of the company. Most of the members of the project were engineers from the Process Technology (PT) Department at the site. Also the project leader was a process engineer from the PT department. No consultants or supplier staff were involved.

Some of the staff working in the project were, however, from other parts of the organisation than PT. A Work Station Manager represented Manufacturing in the project. The Site Environmental Advisor handled contacts with SEPA (and the lab in England), and monitored the potential impact on the ETP from the proposed

[170] Process engineer - project leader

[171] Process engineer - project leader

[172] Process engineer - project leader

[173] Work station manager

technological solutions. The Environmental Technology Consultant (affiliated with the PT department, but formally corporate staff) led an early PTD SHE study. A Corporate Safety Advisor led another of the PTD SHE studies.

6.2.3 Decision points

This section will describe some of the main decisions made in the project relating to the technological and environmental aspects of the project. Some of the issues were disputed. The controversies were between the (external) customer and Chemicals Scotland.

Early on in the project alternative chemical reaction routes were investigated, but none was found. This work was done as part of PTD-SHE study 0, and led by the Environmental Technology Consultant.

6.2.3.1 Toxic effluent

One of the environmental problems encountered was that some of the chemicals involved, including both the raw material and the product, are toxic. The effluent from the process is therefore also toxic. The chemicals are toxic to humans as well as for fish in the recipient water body, should the effluent by accident end up there, and for microbes, which could disrupt the functioning of the effluent treatment plant.[174] Apart from in-house testing, tests and analyses for human toxicity were also made by the customer, and tests and analyses for aquatic toxicity (fish) and micro-toxicity (microbes)[175] were made by the English lab.[176]

Containment was the basic solution strategy to deal with the toxic effluent.[177] An investigated design change for the effluent was a trip alarm system alerting staff to

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[174] Safety advisor

[175] Criteria used were COD levels – measure of micro-toxicity - and probabilities of spillages.

[176] Site environmental advisor

[177] Process engineer - project leader

overflow from the open tanks, but hazards analysis showed that this was not necessary. Another design change was to reduce the toxicity of the effluent by UV radiation. Extra operator checks would also have been necessary. It was however shown that the acidity of the existent effluent would help reduce the toxicity.[178] Furthermore, the microbe flora of the effluent treatment plant managed to adapt to the new effluent. The microbe adaptation was helped by a soft start, where at first only small amounts of the effluent was sent to the treatment plant. It was, however, necessary to use a large storage tank to even out the flow to the treatment plant. A large amount of work and money was spent on dealing with the toxicity problem.[179]

There was initially a leakage where the product was filled into the transport vessels. This was primarily seen as an occupational health problem, rather than an environmental one. The problem was pointed out several times early on by the work station manager, but was not acknowledged by the others in the project. At the time of the start-up review, the problem was acknowledged. The solution was to set up new hoods and, later, antistatic hoovers.[180] The customer was unhappy about the spillage.

The vessels themselves also leaked, which caused a dispute with the customer. The product eroded the rubber of the lining of the vessels. The solution was eventually to replace the rubber lined vessels with much more costly enamel lined ones.[181]

The rubber lined vessels also created another problem. Initially the customer complained about black specks in the product, which turned out to come from the rubber linings.[182] As this was not covered by the product specs from the customer, there was a dispute as to whether Chemicals Scotland needed to do anything about this. In the end they did solve the problem.

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[178] Site environmental advisor

[179] Process engineer - project leader

[180] Work station manager

[181] Work station manager

[182] Work station manager

6.2.3.2 Volatile organic compounds (VOCs)

Apart from the toxicity related problems, there were also problems with the volatility of a solvent used. This required a new agreement with the environmental regulator (SEPA) about VOC emissions standards, since the site had not had any VOC emissions before. A new agreement was reached after lengthy negotiations.[183]

Some of the chemicals involved are highly explosive when in contact with oxygen. After risk analyses it was decided that a nitrogen ballast was needed to keep oxygen out of the process, and thus reduce the risk of explosion and to abide by safety regulations.[184] The nitrogen ballast also helped contain the volatile compounds.

Apart from that, planned releases were also introduced, and the gas from them sent to a condenser. The gas could then be recovered and reused.[185]

6.2.3.3 Other gases

A third problem related to the sulphur dioxide content of the ventilation gases. Testing and analysis was carried out, including wind modelling. The solution was to send the gases to an existing scrubber, which had enough free capacity. (The effluent from the scrubber goes to the effluent treatment plant).[186]

Back balance vents were introduced to deal with nitrogen gases leaking when tanks were filled.[187] The vents lead the gases back to the emptied tank. Back balance vents were also used to contain the volatile solvent.

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[183] Process engineer - project leader

[184] Safety advisor

[185] Process engineer - project leader

[186] Process engineer - project leader

[187] Work station manager

6.2.4 Discussion

The project was successful in terms of getting the new process up and running. At the time of the interviews production was under way.

The main environmental aspects of the project were toxic effluents and the VOC emissions. The VOCs could be dealt with by getting a new permit from SEPA and by using existing equipment. The toxic effluent was dealt with mainly by containment and by using existing end-of-pipe equipment including the ETP. The main decision points are summarised in table 6.3.

The project strategy was to comply with regulation, whilst minimising costs. There were also large overlaps between environmental and safety concerns. Compliance with safety regulations was also important.

Table 6.3 Decision points Chemicals Scotland

Decision points	Arguments for	and against
project as a whole	*new business*	
core technology		
chemical route change (no)		none found
higher efficiency (no)	capacity, RE	planned for a later date
nitrogen ballast	H&S reg., avoiding explosion	
enamel vessels	customer, H&S, E	
end-of-pipe technology		
ETP, soft start, storage tank	reg., cost	
- UV (no)	reg.	not necessary, cost
recovery of VOC	reg., cost	
scrubbing of SO2	reg., cost	
back balance vents	reg.	cost
hoods and hoovers	customer, H&S	cost

Notes: 1) Abbreviations used: reg. = regulation, E = environmental, RE = resource efficiency, H&S = health and safety.

2) Items proceeded with a '-' means that they were alternative solutions to the next item above without a '-'. Items follow by '(no)' means that this option was not chosen.

Several interviewees said that Chemicals Scotland had "*a good working relationship*" with the regulator.[188] There were, however, also some complaints about how long time it took to get the new VOC agreement and how much information they required. There were also differing statements made about how useful the technological ideas coming from the regulator were. The company nevertheless got the permit and permit conditions needed. Pressure from SEPA was not considered very strong.[189] The company however complied with the regulation.

Resource efficiency improvement was not a central aim of the project. The new production line was set up, and substantial optimisation to increase capacity and improve efficiency was planned to take place after the project. The nitrogen ballast is the main example of core technology investments that improved environmental performance.[190] The nitrogen ballast can be given the label cleaner technology since it reduced the amount of emissions produced. But, interestingly, it did not improve resource efficiency. Nor was it introduced with the intention of reducing emissions. This was a fortunate side effect rather than an aim.

The main environmental measures were end-of-pipe rather than cleaner technology, mainly drawing on existing equipment, thus avoiding a large share of the potential costs of end-of-pipe investments.

The company's organisation is well set up for dealing with the environmental aspects of its technology. This is mainly because of its substantive PT department with a considerable number of engineers (and scientists), but also because of its general environmental expertise.

It is also worth noticing that the environmental organisation spans the environment-technology boundary. The company has a specialist on environmental

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[188] Although, as mentioned in chapter 4, my contacts with the regulator staff somehow managed to cause a great deal of disturbance, which suggests that the relationship was rather fragile.

[189] Technical Director

[190] Depending on where one draws the line between the production process and transport, the enamel vessels could perhaps also be considered cleaner technology.

technology, and the Technical Director is part of the environmental-technological network. Whilst the Site Environmental Advisor was mainly involved with getting the new permit and generally liaising with SEPA, the Environmental Technology Consultant led an early SHE study, which had the potential of changing the core chemical process.

As mentioned above, the Site Environmental Advisor had gotten his job mainly through having good contacts with the regulator, in spite of limited environmental expertise. This testifies to the importance paid to the relationship with the regulator, but also to the limited role of the advisor in the project.

7 Dairy industry cases

We shall here present the two dairy industry case studies. As in the previous chapter, one each from Sweden and Scotland.

The Dairy Sweden case is the largest investment project studied, but perhaps the one with the lowest environmental ambitions. The relationship between the regulator and the company is interesting, both in terms of the role of a third party – the Municipal effluents treatment utility – and the regulator's focus on the procedural aspects of compliance, which contrasts with the virtual absence of any material compliance. The Dairy Scotland case stands out in the disconnection between the environmental organisation and the investment project. The company has a formal, relatively ambitious environmental organisation, which, however, had close to no impact on the investment project studied. The late intervention from the regulator (Scottish Water) also makes it an interesting case of what happens when environmental motives are added 'after the fact'.

7.1 Case study: Dairy Sweden

As in the previous chapter, this case study is divided in four parts. The first part gives a background to the study. The second part introduces the project studied. The third part describes some of the main decision points in the project and the differing opinions with relation to those decisions. The fourth and last part will discuss some themes from the case.

7.1.1 Background

This section will give the background to the case study, in terms of the company, the site, and their organisations. Special attention will be given to the engineering capacity and to environmental aspects of the site.

7.1.1.1 The company

The company is one of Sweden's largest dairy companies. It is a producer cooperative owned by dairy farmers. The company structure changed during the project studied after a merger between Dairy Sweden and a Danish cooperative dairy company in 2000.[191] Headquarters are now in Denmark, and the former Swedish headquarter in Stockholm now houses the management of Division Sweden.

The merger between Dairy Sweden and the Danish dairy company has been followed by a series of acquisitions. The largest market is today the UK, after the acquisition of a majority holding in a UK dairy company in 2003.[192] The company now has approximately 70 dairy plants and around 21 000 employees.[193]

The Swedish dairy market is undergoing change due to increasing international competition. Dairy Sweden has for a long time enjoyed a very strong position in the Swedish dairy product market.[194] Competition on basic milk products used to be strong only in a few localities, leaving Dairy Sweden in a virtually unchallenged position in most of its regional market. There was more competition on cheese and specialty products (for example yoghurts).

Now foreign dairy companies, for example the Finnish company Vallio, have entered the Swedish dairy product market.[195] Competition is still strongest in the long longevity specialty products, for example yoghurts. This is also the market segment exhibiting the largest growth.

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[191] Current Environmental Coordinator

[192] Annual report

[193] Annual report

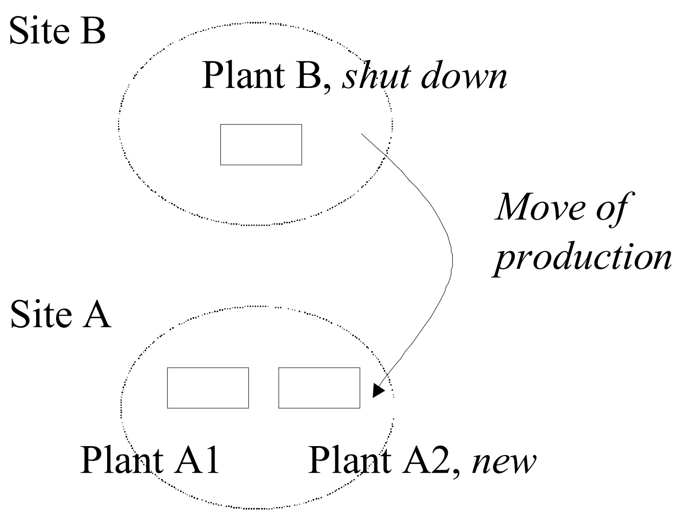
[194] As mentioned in chapter 5, the Swedish dairy market was until recently effectively three regional monopolies.

[195] Current Environmental Coordinator

7.1.1.2 The site

The case study is of a project at a site (site A, see figure 7.1) in eastern Sweden, which before the project produced a limited number of basic milk products (skimmed and whole milk, cream and 'filmjölk'[196]).[197] The plant (plant A1) has a few lines for the production of these basic milk products, produced by continuous processing.

Figure 7.1 Sites and plants



The project included a move of the production of specialty products from a site (site B) in a nearby town.[198] The two sites are 3 miles apart. A new plant (A2) was built for this purpose next to plant A1. The site is now one of the company's two centres for the production of so called 'cup products'.[199] Plant A2 now produces specialty products in batch production. The total number of products is more than 100.

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[196] 'Sour milk', a Swedish fermented milk product.

[197] Corporate Environmental Specialist

[198] Corporate Environmental Specialist

[199] Bägarprodukter. For example yoghurt packaged in portion-sized plastic cups.

Before the move the combined number of employees was approximately 530. Today the total is around 350 employees.[200]

There is a Technical Department at the site, with approximately 40 employees, most of who work with maintenance, but also with investments, purchasing, etc. Some of the technology staff are project leaders with responsibilities for particular areas, including ‘projects’, that is, investments.

There is also some technology staff at corporate level. They are by and large active in the same areas as the local technical staff, but get involved only in larger projects.[201] (There is also at division level a so-called Innovation Department responsible for product development, but it was not directly involved in this project).

7.1.1.3 The environment

The main environmental aspects to dairy plants are the loss of product to waste, chemicals usage – mainly for cleaning and waste treatment – and energy consumption (cleaning of equipment, heating and cooling of the products).[202]

A main reason for the loss of product to waste is caused by switching from one product to another. Sometimes the flow of the new product is used to expel the remaining old product. The part of the flow where the two products mix is separated out as a special waste flow called ‘switch milk’.[203] Sometimes it is necessary to rinse the equipment with water between products, and then clean it with a strong lye solution. This is the main use of chemicals in the plant. The rinse and the cleaning produce two waste flows: the rinse water and the cleaning liquid.

There are possibilities to reuse the rinse water – a mixture of milk and water also known as ‘white water’. The rinse water can sometimes be reused for later rinses.

[200] Technical Manager

[201] Technology Manager

[202] There are important environmental impacts from the transport of raw materials and products as well, but that is outside the scope of this study.

[203] My translation of the Swedish ‘gränsmjölk’.

Some of the white water is regularly sent to a local biogas plant.[204] The remaining rinse water and the used cleaning liquids are treated by treatment works run by the local Municipality. Dairy Sweden is the single largest source of effluents for the works. Before piping the waste to the works, some of this waste stream with a high pH caused by the cleaning chemicals is neutralised at the site.[205] Dairy Sweden pays the Municipality for treating the effluent.

The plant has two boilers fuelled with oil providing energy. The company also buys in steam from a Municipality-owned energy plant. The most energy demanding part of the process is the cleaning, where hot water and water vapour are used.

The site has an environmental permit, which is granted by the County and monitored mainly by the Municipality environmental unit. The permit specifies limits to releases of liquid waste in terms of among other things volume, organic content and pH.[206] The permit also specifies that the company investigate various technological options (more on this later).

Before any major investment, the permit requires the company to do environmental impact assessments and show that they are using best available technology.[207] The permit does not necessarily specify what this is; the company has to show that there are no better practicable options.

The company also has an environmental management system, and has set environmental targets for its activities.

At the site there is one employee working half time with environmental coordination. The Environmental Coordinator convenes a group of employees from different parts of the site dealing with environmental issues. A main responsibility of the local

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[204] Municipality Environmental Officer

[205] Consultant/Project leader

[206] Application for new permit

[207] Municipality Environmental Officer

Environmental Coordinator is to deal with issues relating to the environmental permit and contacts with the regulators.[208]

At the corporate level there is a group of four environmental specialists, which are contact persons for different parts of the division, as well as specialising in various environmental areas like chemicals, transport and permits.[209]

The environmental coordinator left the company after the project, and was later replaced. Meanwhile the position was moved to another part of the site organisation, under the controlling function. This was in part due to a rationalisation as the position of operational coordinator was reduced from a full time to half time job, and the two positions were merged.[210] This may not be the only reason why this happened though.

There were differing opinions about this move. The subsequent environmental coordinator said she regretted not working closer with the technology staff, as good relations with them was of great importance to her job. A member of the Technology Department, who had previously been manager of that department, argued that the environmental coordinator's job was basically a monitoring and control type job, and that it should therefore be kept separate from the technology work oriented towards creating new technical solutions and potentially new environmental problems.[211] This implies that he saw environmental considerations as something that should be taken after the fact, rather than proactively when developing new technical solutions. He further pointed to the risk of environmental work being crowded out economically in the technology department:

> *It can very easily happen that you put all that to one side. At least so long as no one goes to jail, like someone said.*

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[208] Former Environmental Coordinator

[209] Corporate Environmental Specialist

[210] Current Environmental Coordinator

[211] Site Engineer

This view was echoed by the current Technology Manager, who emphasised that having a full time environmental coordinator was uneconomical, that is, to his mind there was not enough work for an environmental coordinator to do for a full time position.

This change also meant a reduction in local environmental expertise. Before the project there was one Environmental Coordinator at each of the two sites.[212] Now there is one, and she does environmental work only half time. In contrast the current number of site engineers is larger than what existed in total at the two sites previously.

7.1.2 The project

This section introduces the project studied. Firstly, by setting out the scope of the project. Secondly, by describing the main motives behind the project. Lastly, the way the project was organised is presented.

7.1.2.1 Scope

The project's origin lay in an investigation about the re-localisation of the production of speciality products. One of the options investigated was to concentrate the production of specialty products. By concentrating production Dairy Sweden hoped to achieve better use of existing equipment, as well as creating larger groups of employees with expertise on specialty products.[213]

A decision was made that the specialty products produced at site B were to be moved to site A. The plant on site B was old and perceived to not be amenable to reconstruction or expansion.[214]

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[212] Environmental Coordinator
[213] Technology Director

[214] Current Environmental Coordinator

This case study will focus on this investment project, which ran from the start of 1999 towards the end of 2001. As mentioned above, the main part of the project was constructing a new plant (A2) beside the existing one (A1) on site A, and moving the production of specialty products at site B into the new plant (A2).

As part of the investigation an Environmental Impact Assessment (EIA) was performed. The environmental permit specifies that Dairy Sweden has to do an EIA for all major changes of production.[215] The EIA was produced by a local consultancy firm. The assessment showed that fewer plants and newer equipment would lead to more efficient plants and reduced waste. On the other hand increased transportation would offset those gains and the net effect was slightly worse environmental performance.[216]

In 1998, before the main project started, a small part of the production at plant B (non-flavoured yoghurt and sour cream) was moved to plant A1.[217] During the main project more of the equipment was brought from plant B to the new plant (A2), but some new equipment was also bought in.[218]

Some changes to the existing plant at site A (plant A1) were also made as part of the investment project. An automated control system and an IT business system were introduced, replacing earlier manual handling of production control.

The original budget was 430 million SEK.[219] Additions were later made to the project, so that the budget then totalled 530 million SEK.[220] The project ended up costing more than the revised budget.

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215 Municipality Environmental Officer

216 Corporate Project Manager

217 Application for a new environmental permit

218 Consultant/Project Leader

219 Approximately £31m.

220 Approximately £39m. Corporate Project Manager – note that this was not the project leader, and that ‘Project Manager’ here is a position rather than a role in the project.

7.1.2.2 Motives

A main motive for the project was increased production capacity, including the possibility for future expansion, mainly in the growing area of specialty products.[221] A second main motive was increased cost efficiency. This was to be achieved through better utilization of equipment, and through a reduction of the number of employees.[222]

Environmental considerations were not given high priority in the project. The environmental improvements that resulted were side effects. The site engineer elaborated on this:

> *When it comes to the environmental part… The target was really flexibility, and reduced product losses. And with the losses, there's an environmental gain. And with the general improved efficiency you also improve environmentally. There's hopefully less energy use and all that.*

The permit was renewed first in 1999, when it was clear that the production at site B was to be moved to site A.[223] (The permit was renewed again after the project, in 2003, in part because the amount of organic substance in the effluent was too high.)

The company itself proposed the level of organic substance in the wastewater of the first permit. It was calculated by adding the production of site B and by extrapolating some trends.[224] According to the corporate environmental expert who did the calculations, the level was also set "*for pedagogical reasons*", implying that the company thought they could have managed a lower level. The environmental authority subsequently approved the proposed level. Notably, the Municipality effluent treatment works also approved of the level. The dairy plant effluent is the main load on their plant, and the carbon of the waste stream is actually beneficial to the carbon nitrogen balance of the biological treatment at the works.[225]

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[221] Consultant/Project leader
[222] Technology Director
[223] Corporate Environmental Specialist

[224] Corporate Environmental Specialist

[225] Environmental Consultant

7.1.2.3 Project organisation

The project reported to a company steering group, chaired by the corporate Technical Director, who was also responsible at corporate level for environmental affairs.

The project went through several phases, each with its own formal organisation.[226] After the re-localisation investigation (with contributions from site staff), there was a planning phase detailing the requirements for the project. Then followed a programme phase dealing with the technological and organisational solutions to those requirements. After that, followed a construction phase, and lastly an implementation phase. After the project further optimisation was needed. The number of participants varied greatly. In some phases, notably in the construction and implementation phases, several hundred people were working on the project.

The project organisation for each phase was also divided into 'functions' like quality, process technology, purchasing etc.

The project was also complex in terms of the involvement of people from different organisations. Two construction companies were hired to build the new plant.[227] Two process equipment suppliers - Supplier Sweden and Supplier Denmark - supplied most of the new equipment. In addition to this there were several other companies involved supplying various specialised products and services.

Two consultancies were heavily involved in the project. The main project leader and his closest co-worker were from a consultancy, Plant Tech, oriented towards the construction of labs and manufacturing plants.[228]

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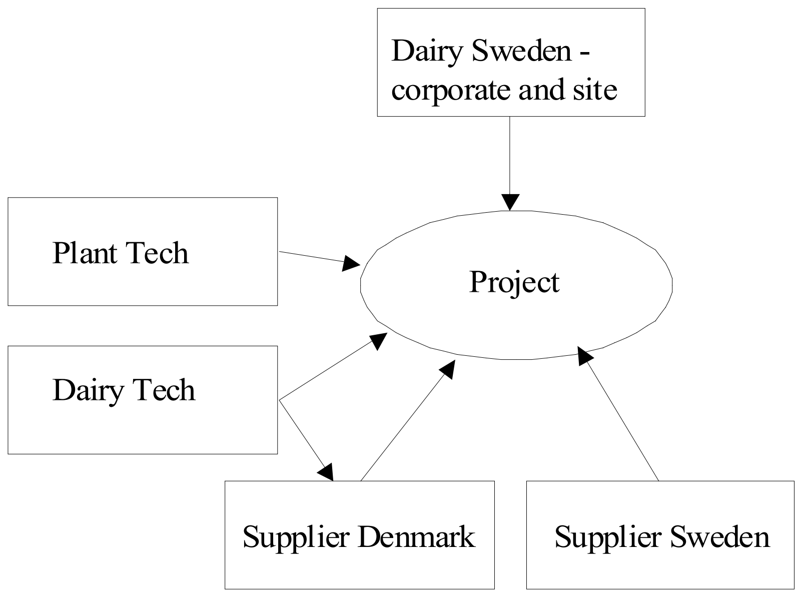
[226] Consultant/Project leader
[227] Consultant/Project leader

[228] Consultant/Project leader

Figure 7.2 Some of the main companies involved in the project



The largest number of consultants came from a consultancy, Dairy Tech,[229] which specialised in dairy process technology. The Dairy Tech consultants were hired by Dairy Sweden to work in the planning phase of the project.[230] These consultants did several things including simulations and leading parts of the project. Some Dairy Tech employees were also hired by Supplier Denmark to work on the project in the implementation phase.

The contacts with the environmental authorities and the utility were managed by the environmental staff, and this work did not involve the technical staff nor the other project workers even though reducing the loss of raw materials to the waste stream was one focus of the project work. In the words of one of the site engineers:

> *The permit was handled by [the division level environmental expert]. We didn't see anything of that in the project.*

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[229] Dairy Tech had previously been the central, technical division of Dairy Sweden, but was spun off approximately 15 years prior to the project. Dairy Tech was spun off after a period of intensive plant construction in the hope of getting contracts from other dairy firms. Dairy Sweden at first kept a minority share of the company, but later sold all shares. The consultancy had been traded a few times after that and was at the time of this project part of a larger engineering consultancy. In spite of this, contracts from other dairies have been scarce and Dairy Sweden had continuously been their

[230] Consultant/Project leader

The local environmental coordinator, who was positioned in the Technology Department, did have a role in the investment project. In his own words, his job was to "*be the environmental controller of the dairy into the project*". His role has not been mentioned by any of the other project workers. His words also hint at a monitoring and control orientation of his work and of his role in the project, rather than a more proactive or cooperative role.

7.1.3 Decision points

This section will describe some of the main decisions made in the project relating to the technological and environmental aspects of the project.

7.1.3.1 Energy

In an early phase when the various project requirements were translated into a more concrete design for the new plant, the project team realised that the planned costs would severely exceed the project budget. This led to an effort to reduce the costs through a range of changes to the design.[231]

Most of these cuts did not have any direct environmental effects, but one of the cuts made was to replace a planned additional oil fuelled boiler with energy from the district heating plant.[232] The decommissioned plant had had an oil-fuelled boiler. There were discussions with the Municipality-owned energy company and with a professor of energy systems from the university in town about how to solve the heating function.

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[231] Some changes were made to the core process, including the omission of some valves and interconnections between different pieces of equipment, thus losing some of the production flexibility. Mostly though, it was other so-called 'side-functions' that had caused the increase in projected costs, and this is where most of the cuts were made. This included a smaller building offering somewhat less space for future expansion, and less floor space between machines, though still within the limits set by the government Occupational Health and Safety Board. These changes had little environmental impact.

[232] Technology Director

The need to cut costs thus contributed to the switch from the investment in a boiler to signing up for district heating. The Technical Director (who was also the internal customer) also claimed that she took a stand for this for environmental reasons:

> *Because I insisted on that, to not install new oil fuelled boilers in existing, durable plants. It was like: here, but no further.*

Reducing the energy costs was however an aim in the project, mostly for cost reasons.[233] Heat exchange technology was used extensively. The Dairy Tech engineer however claimed that more use of heat exchange could have been made in relation to the cleaning process, but that this would mean too high investment costs.

The process lines in the new plant were arranged vertically rather than in the traditional horizontal configuration.[234] One reason for this was to benefit from gravity in propelling the process flows between different stages of the process. This solution was also more compact and offered shorter distances between different pieces of equipment, thus reducing pipe length. Reduced pipe length means a smaller use of cleaning liquids and less product waste. On the other hand the tower built to encompass the vertical lines was in some ways difficult to ventilate and to keep at the right temperature.

This problem was exacerbated by the wish to have a glass wall on one side of the plant.[235] This was done to exhibit the process to the town population. The glass wall transmits heat both out of and into the plant, in ways that is not desirable, which adds to the ventilation and heating problem. This solution is not energy efficient, and there was on-going cooperation with the local university to deal with this after the project ended.

7.1.3.2 Product losses

One of the design parameters of the project was to reduce the fraction of raw materials being lost to waste. A main driver for reducing the product losses was the aim to improve cost efficiency, which was reflected in special attention given to the

[233] Consultant/Project leader
[234] Site Engineer
[235] Site Engineer

loss of more expensive raw materials, for example the jams used for flavoured yoghurts and other products.[236] The consultant Project Leader explained:

> *Now, the amount of jam used is decisive for the price of the product. And when you change the product often, and clean in between, a lot of jam disappears in the drains, and it's at least ten times more expensive than the product. And because of that it is very important that you make sure to minimise the losses.*

The Technology Manager also expressed a concern for losing "*our owners' products*" as a problem in itself, which reflects the fact that the company is owned by dairy farmers.

Although reducing product losses was not a core motive behind the move of production, the switch from the old manual plant to the new automated one in itself helped in reducing losses according to the plant Technical Manager. The Dairy Tech engineer specified this further by saying that automation gives better hygiene, which reduces the need for cleaning.

During the project it was discovered that the amounts of organic substance in the waste stream were higher than expected.[237] There were several reasons for this, one of which was the increasing range of products that required more frequent cleaning of the equipment.[238] The new products were also on average fattier than the old ones, which made emptying the equipment more difficult and resulted in more material being lost in cleaning. The increased use of fatty raw materials however boosted the attention to reducing product losses in the project.

There was a special limit in the environmental permit for the release of fat[239] and the Municipality Environmental Department was concerned about the company not keeping within the limit. The Municipality run treatment works did not however mind the extra fat, which diffused the pressure from the Municipality.[240] There was then a discussion whether to immediately apply for a change in the permit. It was

[236] Environmental Consultant

[237] Corporate Environmental Specialist

[238] Environmental Coordinator

[239] Separable fatty acids

[240] Environmental Coordinator

decided to wait until after the project, when there was to be a new application for an environmental permit anyway. The environmental expert and the local environmental coordinator made this decision.[241]

Several ideas were suggested for reducing product losses, some of which were implemented, others not. There was some discussion regarding the possibility of having longer batches, and thus reducing the need for cleaning. The Municipality Environmental Department supported this idea. The corporate level product development staff had however set limits for batch lengths due to hygiene and longevity reasons, and the idea was not implemented.[242]

Separation of waste flows allows more choice in managing them. One measure introduced in the project to improve separation was to introduce new sensors: conductivity meters, which facilitated improved flow control and separation.[243] This meant that the white water could be separated out better from the other rinse liquids.

Another measure was to build a new waste stream measurement facility, enabling the engineers to more accurately and quickly locate problems in production causing irregular waste flows.[244] This was done on the initiative of one of the local engineers, who had had experience of the difficulty in the existing plant of locating the source of irregular waste flows. Special money was allocated to this addition to the project.

There was also an idea to introduce longer times for draining the equipment after batches, thus gaining more product and reducing losses. This would however have meant longer gaps between batches, and was turned down because of its impact on production economy.[245]

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[241] Environmental Coordinator

[242] Corporate Environmental Specialist

[243] Corporate Environmental Specialist

[244] Site Engineer

[245] Corporate Environmental Specialist

It is sometimes possible to expel a product from the equipment using the following product without cleaning the equipment between the batches.[246] This is acceptable if the second of the products is more flavoured than the preceding one. Production runs are thus run in sequence - called campaigns - from unflavoured to heavily flavoured.[247] Campaigns were introduced.

An alternative to expelling a product from the process with the following product is to clean the equipment using pigging technology. Pigging technology works by propelling a pig - a soft ball - through the pipes. The Danish process technology supplier proposed this, but the idea was abandoned during the budget crisis mentioned above.

One reason for abandoning this technology was the high investment cost of the technology.[248] Pigs require special valves in the piping and these valves are more expensive than ordinary ones. There were also concerns about the degree of flexibility pigging technology offers in terms of being able to reconfigure the equipment. There were also questions about hygiene when using pigs. A visit to a cosmetics and hygiene products company who were using the technology however showed that this would not be a problem. Finally, both the site engineer and the corporate Project Manager mentioned a lack of in-house experience of this technology as a reason for not going ahead with it.[249] The Project Manager said: "*We do very little technology development, and perhaps had not enough internal competence for this*".

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[246] Consultant Engineer, Dairy Tech

[247] It is actually a bit more complicated than that. For example, it is also a matter of fat content.

[248] Site Engineer, Corporate Project Manager

[249] Site Engineer, Corporate Project Manager

7.1.3.3 Chemicals use and waste treatment

As mentioned above increased automation could be expected to lead to a reduced need for cleaning, which might reduce chemicals usage. The project also introduced a Cleaning In Place (CIP) system, thus automating the cleaning process itself.

One waste stream from the cleaning is strongly alkaline from the use of lye. It is neutralised in a special utility by mixing in a strong acid. The neutralisation utility was expanded in the project by adding another buffering tank due to the increased volume of production.[250] The company also switched to a new, weaker acid (from sulphuric to carbonic acid) in spite of higher cleaning costs.

According to the environmental permit, Dairy Sweden had to investigate the possibility of building a treatment plant on site. This was done by an environmental consultant in a separate project towards the end of the main project (as described in more detail below). The consultant recommended not building it, arguing that it would require the sludge to be transported to the Municipality treatment works anyway, and that it would be costly. The Municipality Environmental Officer interviewed agreed that it would be too costly, and this option was not mentioned in the subsequent renewed permit. An important factor was also, as mentioned above, that the Municipality treatment works needed the organic content of the waste stream for their biological treatment.

7.1.3.4 The cleaner technology investigation[251]

Dairy Sweden also used consultants in the environmental activities running in parallel with the project. The environmental consultancy that had prepared the environmental impact assessment for the project also produced a report setting out possible actions to improve the environmental performance of the reconstructed plant during the project.

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[250] Current Environmental Coordinator

[251] This section is based on the interview with the environmental consultant, unless otherwise stated.

As part of the 1999 environmental permit, the company was required to do an investigation into the possibilities of reducing the amount of organic substance in the wastewater by changes to the production process, or, alternatively, to improve the company internal waste treatment. The report was prepared in response to the permit, and did not originate in the project.[252]

The report was prepared by a consultant, who belongs to a local consultancy firm and had been working for Dairy Sweden many times over the years. Indeed, Dairy Sweden had been his main customer since the beginning of his consultancy career approximately 20 years earlier. The report was produced mainly by interviewing employees at the local site, both white and blue collar staff.

The resulting list of possible actions was compiled from the interviews and set down in the report. The consultant described his input as mainly the compilation of knowledge already existing in the firm, but perhaps existing as isolated islands of knowledge. Thus, a benefit of the report was to gain an overview of already available ideas, rather than bringing new options to the attention of the company.

As mentioned above, the main reason to produce the report was given by the environmental license, rather than by any strategic consideration of environmental issues in the project. This was reflected by little communication between the consultant and the project management. Moreover, there was not much communication between the consultant and the environmental expert responsible for hiring him, nor was the consultant involved in what happened to the report and its recommendations after it was delivered. The work done thus appears to have been an easily specified and easily separable task.

The origin of the report was also reflected in its emphasis on how bad the idea was to invest in a new waste treatment plant. The consultant admitted to having placed some additional emphasis on this, whilst also stressing his belief in the correctness of the emphasis, to fit in with the company's agenda in relation to environmental authorities:

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[252] Environmental Coordinator

So I've chosen the wording a bit in that direction. Even if factually it is that way, certainly. But you do emphasise the image that it is a completely insane idea to have an internal treatment plant in a food industry etc, etc. And that's the way you do that, a bit. Maybe you'd been more to the point and candid if it had been a fully internal investigation they'd ordered. Because now it will be dealt with by a regulator.

The report had little direct impact on the parallel investment project,[253] partly because that was not the intention behind commissioning the report, but it was also a matter of timing since the report was produced towards the end of the project. In spite of the limited direct impact on the project, several of the options mentioned in the report have subsequently been implemented as part of the ongoing effort in and after the project to reduce the amount of raw material lost to waste. This is perhaps not so surprising as the report mainly summarised already existing ideas. The report from the cleaner technology investigation was appended to the new permit application in 2003.

7.1.3.5 Implementation

The installation of the new equipment was delayed due to problems with the construction of the new building.[254] The efficiency improvements promised in the Environmental Impact Assessment were not fully realised.[255] This caused some friction between Dairy Sweden and Supplier Denmark. These delays also meant that the time available for optimisation in the project was reduced.

Subsequent further optimisation work reduced the problem, but discharge levels were still high. After the project, in 2003, when the environmental permit was renewed the discharge limits were increased to reflect the higher level.[256]

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[253] Corporate Environmental Specialist

[254] Consultant/Project Leader

[255] Corporate Environmental Specialist

[256] Current Environmental Coordinator

7.1.4 Discussion

The project was by and large successful, although costly. The new plant was more efficient than the decommissioned one, and the quality of the products was good.[257] Environmental improvement was never a core motive for the project, and the outcome in environmental terms was mixed.

As described above, the fat content of the discharges were too high during the project. The (delayed) optimisation efforts at the end of and after the project somewhat reduced this problem. Right after the end of the project the company applied for a new environmental permit, and was then granted a more generous condition regarding organic substances.[258]

Table 7.1 Decision points Dairy Sweden

Decision points	Arguments for	and against
project	*capacity, cost eff.*	
core technology		
heat exchange	RE	
more heat exchange (no)	RE	investment cost
district heating	cost, E	
vertical plant, glass wall	capacity, image, RE	
automation (before project)	RE	
sensors	RE	
measurement facility	efficient trouble shooting	
campaigns	RE	
longer batches (no)	RE	hygiene/longevity
draining times (no)	RE	prod. econ.
pigging (no)	RE	cost, flexibility, lack of experience
CIP automation	RE	
weaker cleaning acid	reg.	

Note: Abbreviations used: reg. = regulation, E = environmental, RE = resource efficiency, Q = quality, eff. = efficiency, prod. econ. = production economy.

[257] Technology Director
[258] Corporate Environmental Specialist

There was little effective pressure from the regulators. In part this was because the Municipality treatment works were happy to receive the effluent, irrespective of whether it was above permit limits or not. The Environmental Department in the end accepted the case made by Dairy Sweden and the treatment works for higher discharges. In contrast, the cooperation with the Municipality energy company resulted in improved environmental performance.

The Municipality Environmental Officer stressed that Dairy Sweden performs well, and that their environmental organisation is well structured. From the point of view of the Municipality the relationship is an open one. It is hard to see any direct link between the limits set in the permit and the changes made in the project. There appears to have been a cooperative relationship, not least on behalf of the regulator.

In terms of environmental innovations this case is mostly about the environmental benefits gained from business-as-usual efficiency motivated investments. This is clearly shown by the efforts to reduce product losses. Investments were made that improved efficiency and as a side effect environmental performance, unless costs were seen to be too high. The only exception seems to be the switch to a weaker cleaning acid, which yielded no efficiency gains and meant higher costs.

No end-of-pipe investments were made, reflecting the weak regulatory pressure. Several of the technologies invested in could be described as cleaner technology, in that they improved environmental performance whilst also giving economic benefits. This was almost without exception not intentional environmental improvement though. Nor were these decisions related to regulatory compliance.

The exception is the deal with the Municipality regarding district heating championed by the Technical Director cum internal customer. Here environmental improvement was an explicit motive, alongside cost savings. It is interesting that the Technical Director had (like the internal customer at Chemicals Sweden) benefited in her career originating in engineering from doing environmental work.

Apart from this, there was a very clear separation between environmental and technological work in the project. Environmentally motivated initiatives either by environmental or technological staff had little role to play in technical developments. For example, the work on the permit was managed by the corporate environmental expert with the help of the local environmental coordinator, and had virtually no impact on the project. We even saw, in relation to the move of the environmental coordinator position after the project, that there was some resistance among the engineers to cooperating with the environmental staff.

A further testimony to the separation between technology and environment is given by the report prepared by the environmental consultant. That task was intimately tied up with the work relating to the environmental permits, and in spite of its relevance for planning technological improvements, it was not extensively used as an input for that.

7.2 Case study: Dairy Scotland

This case study is structured in the same way as the previous ones.

7.2.1 Background

This section will give the background to the case study, in terms of the company, the site, and their organisations. Special attention will be given to the engineering capacity and to environmental aspects of the site.

7.2.1.1 The company

Dairy Scotland is one of the three largest dairy companies in the UK. Its origins lie in Scotland, but the head quarters are now in England. The company has approximately 3 000 employees, and operates five dairies and more than ten depots. In addition to these sites, operations include the distribution of milk. The company has been expanding at a rapid pace through acquisitions from the 1970s onwards, and since the late 1980s also through the construction of three new plants.[259]

The company is strongly focussed on the production of milk. Apart from milk it also produces some juice, cream and ice cream, but unlike the other major dairy companies no cheese. Supermarkets represent a large part of the sales. The company has been doing well financially. It is listed on the London Stock Exchange.[260]

7.2.1.2 The site

The site studied is located in Scotland. The plant is one of the older, smaller plants of the company and was up until the project studied largely manual in operation. The only part of the plant to have been automated before was the cleaning in place (CIP) unit.[261]

The plant has a wider range of products than the newer plants. Apart from the basic skimmed, semi-skimmed and whole milk, production at this site includes school milk, organic milk, GM free milk, cream and juice.[262] This relatively large range of products requires a large number of different packaging types and packaging machines, but also that the production is run in batches with frequent changeovers.

There is at central level a Technical Director, reporting to the Productions Director. The Technical Director is responsible for maintenance, engineering and environmental management. Working for the Technical Director are three specialist managers, one for each of these areas. At site level there are engineering teams of four to five engineers dealing mostly with maintenance. This means that most

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[259] Annual report

[260] Annual report

[261] 'Cleaning in place' systems allow cleaning of equipment (and pipes) without opening or dismantling any of the equipment.

[262] Technical Director

technical staff work with maintenance. There were plans to increase the number of people working on engineering at the site level.[263]

Investment ideas are compiled annually by the Technical Director.[264] After deciding which ideas are to be given priority budgets are allocated to the sites for projects run by site project champions. If a project is deemed to be high risk or high cost, group level staff may retain control of the budget and the project leadership. This procedure has been made more formal in recent years, and for any substantial investment a detailed justification needs to be written, whereas previously things were done in a less elaborate fashion.

7.2.1.3 The environment

The main environmental impact of the plant's operations derives from the liquid effluent. The effluent is discharged via the sewers to the local Scottish Water treatment works, apart from some of the effluent that is sent to a nearby plant for processing in a reverse osmosis recovery plant. The recovered product is sold off. Another environmental aspect of the operations is of course the energy used.

The effluent is made up largely of spillage, discarded product and water from the cleaning of the equipment. The chemicals used for the cleaning give some of the effluent a high pH. The effluent contains fatty and other organic substances from the milk and, not least, the cream. At some times of the year like Christmas and Easter there are peaks in the amount of fat discharged.[265]

The plant is regulated by Scottish Water, but at the time of this study not by SEPA. Scottish Water charges the company for the trade effluent discharged based on the organic content (measured as biological oxygen demand, BOD, and chemical oxygen demand, COD). Scottish Water also sets limiting conditions on the discharge

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[263] Technical Director

[264] Technical Director

[265] Environmental Manager, Trade Effluent Advisor

consent. These conditions concern pH, suspended solids and total fat, but not BOD or COD.[266] There are no reporting requirements in the consent.

In spite of quite ambitious environmental work at the central level, the plant was performing poorly before the investment project studied, with discharges of fatty substances well over consent limits and high pH effluent.[267] Possible reasons for this are a high turnover of site managers slowing down improvement efforts, and a history of little or no attention from Scottish Water with regard to the discharge levels.

The company as a whole has a recent history of environmental work. It started off in the late 1990s with a waste minimisation project driven by the Quality Systems Manager. This led on to an effort starting in 2002 to certify the operations according to ISO 14001. All operations are now so certified. The certification work was led by the Productions Director and, later, the Technical Director.[268] The organisational focus of the environmental work has thus shifted from the quality function to the production and technical functions. The driver for this work has been a desire to be attractive in the eyes of investors and customers.[269] At the moment the focus of the environmental work is applying for IPPC permits, in response to new legislation.

The current environmental organisation, which was set up in 2001, is led by a company level steering group chaired by the Productions Director. Since 2002 there is an Environmental Manager, who leads the day-to-day company level environmental work, and who is the main contact for Scottish Water in the company. The Environmental Manager liaises with an environmental group at each site. The groups are led by local Environmental Champions, usually a production manager. Efforts are made to include maintenance engineers in the site level groups.[270]

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[266] Trade Effluent Advisor

[267] Trade Effluent Advisor

[268] Technical Director

[269] Environmental Manager

[270] Environmental Manager

The Environmental Manager is the only member of staff working exclusively on environmental issues. For some issues consultants are used, for example training and some more technical work like modelling. In early 2004, coinciding with the end of the project studied, a consultant was hired to do a waste minimisation review for all the sites.

The formal organisation at Dairy Scotland is in some ways conducive to the integration of environmental expertise with technological expertise. The Technical Director is also responsible for environmental issues at group level. Environmental work actually started off as part of the remit of the Quality Systems Manager, but the responsibility was later transferred. Both the Technical Director and the Environmental Manager emphasised the benefits of organising technical and environmental work together, in spite of overlaps also with quality and health and safety issues.

Environmental procedures include Environmental Impact Assessments and a risk procedure for investment projects, and the monitoring of the environmental targets of the Environmental Management System.[271] These routines are however relatively new to the company and not quite well established. The Technical Director said:

> *It's very easy to think: you put in a new… new equipment in, without really considering, the cream waste, or the paper waste… You know, it is difficult. We're trying to just put things in place, to make sure that the right people are made aware at the right time, and… because we're still a young company, we're growing very fast, it is difficult. But I think we're getting there. Slowly.*

The plant studied has had no requirement to report environmental performance to regulators, and according to the Environmental Manager the company does not measure environmental performance as well as it ought to.

There is no separate budget for environmentally motivated investments.[272] Ideas for environmental improvements are dealt with in the same way as other suggestions. The Environmental Manager has a role in investment planning and budgeting. When project champions prepare environmental impact assessments, they are supposed to

[271] Technical Director

[272] Technical Director

send them to the Environmental Manager for approval, although this does not always happen.

In spite of the Environmental Manager's formal position reporting to the Technical Director, his tasks do not include any technological work. Furthermore, the Environmental Manager said that he did not work closely with the technology managers (engineering and maintenance) who are also at the HQ and who also report to the Technical Director. The Environmental Manager claimed to want to work more closely with them, but that they were not very interested in this. In contrast, he works increasingly closely with one of the health and safety staff. The Environmental Manager also reported that he did not know the site engineers.

The separation of technology from the job of the Environmental Manager can to some extent be explained by the history of environmental work being driven by the Quality Systems Manager. It is sometimes seen as a management system similar to the quality system, rather than as technology.[273] But the separation is also a matter of expertise. The Environmental Manager explained:

> *A lot of the waste minimisation stuff, I don't have an input in at all, because it's the job of Production Managers, Site Managers, technicians whatever, who have specialist knowledge that I don't have about the dairy process… I think because so much of the job is taken up by legal compliance, and a lot of people-work, I don't have a lot of time to be thinking: how could we improve that? How could we send less trucks to [site x] from [site y], because of air emissions or whatever. I don't have time to actually focus in and look at that. Unfortunately!*

7.2.2 The project

This section introduces the project studied. Firstly, by setting out the scope of the project. Secondly, by describing the main motives behind the project. Lastly, the way the project was organised is presented.

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[273] Technical Director

7.2.2.1 Scope

The project studied mainly concerned the automation of the plant. Previously, the plant had been manual, apart from the cleaning system which was now to be re-automated. In addition to the new automation system, some pieces of equipment – mostly some new pipes and valves – were added. The project also included the introduction of a management information system.

Only part of the plant was automated. The pasteurisers were left manual. After the pasteurisers there are separate lines for milk and cream. The milk lines were fully automated, but the cream lines only partially.[274]

Apart from automation, the project also included efforts to improve the recovery of product from waste streams.

7.2.2.2 Motives

There were several motives behind the project. A central motive for automating the plant was demands from customers on traceability,[275] that is, the ability to document every stage of the processing of an individual product, say a bottle of milk. This could be done manually, but was seen to be facilitated by an automatic system. Automation was also seen to give better repeatability of operations, with the hope of securing an even quality of the products.[276]

Traceability and repeatability could be said to be aspects of the ability of management to control operations, of quality control. A related motive was increased transparency of operations, through the documentation of all operation actions and through the management information system. The supplier software engineer working on the management information system said:

> *And another thing is reporting how things are done, and what. It's like a big brother watching what is done. So it's an audit system.*

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[274] Supplier/ Software engineer

[275] Technical Director, Supplier/ Software engineer

[276] Technical Director

There was also a perception that the plant was run down and in need of upgrading. For example, the existing control system for the cleaning unit was not working well, and also the company did not know very well how it worked.[277] The Technical Director captured a more general sense of moving forwards:

> *Let's do it. Let's bite the bullet. And prove that we're trying to move forwards. And prove the systems. And prove the standards.*

There were also hopes that the automation would improve environmental performance, especially relating to the effluent. This was done partly for cost/efficiency reasons, as product going down the drains is product not sold,[278] but perhaps also as part of the overall environmental work of the company. There was later on regulatory pressure from Scottish Water, but not during the planning of the project. Those pressures were initiated at a later stage. Less emphasis was put on reducing chemicals or energy use, perhaps because of smaller financial incentives.[279]

7.2.2.3 Project organisation

Dairy Scotland has little in terms of in-house staff to do this kind of work, and the design work in the project was performed by a supplier. Dairy Scotland had previously relied on another supply company, but for this project chose the UK firm Process Supplier. Process Supplier had previously quoted for the construction of another plant, and had also more recently been awarded a project improving the reverse osmosis plant at a nearby site.

At first Dairy Scotland had taken in quotes from its regular supplier, but then the Technical Director was employed and got involved with the project, and he wanted to get quotes in from an alternative supplier. One reason for this was to avoid being locked in to the particular solutions of the old supplier. It was hinted that there had also been some problems on a previous project using this supplier.[280]

[277] Supplier/ Senior Project Engineer

[278] Technical Director, Supplier/ Project Manager

[279] Technical Director, Supplier/ Project Manager

[280] Technical Director

The initial planning and supplier procurement had been done by the Production Director, the Site Manager and a Project Champion at the site. Later the Technical Director became Project Manager (internal project customer). The Project Champion was replaced during the project. One of the supervisors on the site was also involved. There were a team of maintenance engineers at the site, but they were not heavily involved.[281] The Environmental Manager was not involved in the project. The Technical Director, in his capacity of Project Manager, took care of the environmental impact assessment.

The dairy industry is a central market niche for Process Supplier, but they also work for other companies like breweries. Process Supplier supplies some types of process equipment and provides design services. The company has approximately 200 employees and is part of an international group of suppliers. The company is based in England.

The project members at Process Supplier were mainly from its Engineering Division doing process as well as mechanical design, and from its Automation Division designing the control system and the management information system. There were also a few commissioning engineers involved as well as electrical and software engineers subcontracted in. The Project Leader had a mechanical design background, and was seconded by a Senior Project Manager from the Automation Division. Process Supplier has no environmental staff.

The design work started with the process engineers. They specified the process on a relatively abstract level embodied in two types of documents: a functional design specification (FDS) and piping and instrumentation diagrams (P&ID).[282] Based on these documents the mechanical designers specified the actual physical layout of the equipment and what specific pieces of equipment to use.[283] Also based on these documents the software engineers designed the software for the control system.

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[281] Supplier/ Senior Project Engineer

[282] Sometimes called process and instrumentation diagrams.

[283] Supplier/ Senior Project Engineer

The project ran from the beginning of 2003 until early 2004. After the plant was up and running, Dairy Scotland was not satisfied with the results and Process Supplier was forced to come back and re-commission the plant.[284] There are remaining problems in the plant, and Process Supplier has subsequently been hired again to optimise things further.

7.2.3 Decision points

This section will describe some of the main decisions made in the project relating to the technological and environmental aspects of the project, especially the focus on recovery.

7.2.3.1 Recovery

The plant collects so-called reclaimed product from for example broken packages, and sells it off. At some dairy companies such reclaim is fed back into the process, but Dairy Scotland does not do this for quality reasons.[285] The reclaimed product is lower grade than the milk going to the supermarkets, but can be used for, for example, cheese production. Since Dairy Scotland does not produce cheese, the reclaimed product is sold to other manufacturers.

One of the major environmental considerations to be taken in this project was the focus on white water recovery. White water is mixed milk and water from for example flushing out the equipment with water (‘piping out’), which is part of the cleaning cycle. The white water was previously sent to the sewers.

In the project studied new recovery tanks were added to collect not only reclaim but also white water from the process. The recovered liquid is then shipped for processing in the recovery plant at the nearby site, and then sold off. Apart from the new tanks efforts were also made to adjust the process, both hardware and software, so as to facilitate the separating out of recoverable white water.

[284] Technical Director

[285] Supplier/ Project Manager

A central motive behind the recovery efforts was to increase revenues, by being able to sell more product. Avoiding putting the white water into the sewers may also reduce the charges from the water authorities, although during the planning stage of the project those charges were low. The Technical Director explained the motive behind the recovery:

> *Our waste is down, costs less money. It helps the environment, but it costs us less money. So I suppose it's financially driven. That's being totally honest!*

Scottish Water had for a long time paid little attention to the discharges from Dairy Scotland. With the hiring of a new Effluent Trade Advisor renewed sampling was made, and the charges were raised considerably. Pressure was also put on the company to reduce the strength of the effluent, especially fatty substances, since they risked causing problems in the treatment works. The advisor said:

> *But I had to say to them at a number of different occasions that if things weren't to improve, then obviously we would have had to look at the option of taking enforcement action, whatever form that took. So, they were aware of that.*

This increased pressure from Scottish Water occurred when the project was well on its way. This led to a strengthened focus on recovery in the project, according to the Technical Director. But the main technical decisions had already been made, and little if any design changes were made because of the increased regulatory pressure.

7.2.3.2 Other environmental issues

Apart from the recovery, the automation has probably given some environmental gains by increasing the accuracy and efficiency of operations. Dairy Scotland and Scottish Water agree that there have been some improvements to the effluent after the re-commissioning of the plant. The increased pressure from Scottish Water also generated more discussion in the project about the environmental aspect of the automation efforts. Again, however, the main decisions had already been made and the awakened environmental interest did not affect the technological solutions chosen.

As mentioned before, there were at some times of the year large peaks in the effluent from the dairy. After pressure from Scottish Water, it was decided to recover the liquid from the washing of the cream tankers coming back from delivery. This liquid had previously been sent to the sewer. The washing now actually takes place at the nearby site with the recovery plant instead of at the site studied. The peaks have been successfully reduced.

There was not much focus on reduced chemicals use in the project. The Technical Director suspected that there might be more chemicals used now than before, due to more cleaning. Neither was energy savings a concern in the project. Some gains were however made since the cleaning is now done in half the time after automation. (There is in fact a trade-off to be made between the strength of the chemicals used and the temperature - and thus the energy usage - of the cleans). The pH of the effluent remains high.

The management information system was not designed to facilitate the monitoring of environmental performance. A lot of relevant data, for example water usage, was included in the system, but not brought together to display environmental performance. The Software Engineer at Process Supplier said that this could relatively easily have been done, but there was no demand for this kind of display.

7.2.4 Discussion

The project was successful in terms of automation delivering traceability, repeatability and transparency. However, after the project there were continuing problems in terms of efficiency relating to the optimisation of the operations of the plant and to parts of the recovery system.[286] There was also some uncertainties relating to the effluents due to the fact that there were not sufficient data on past performance, and it was therefore difficult to measure improvements.[287] The effluent probably improved somewhat.[288] The fat content has been reduced – especially during the Christmas, Easter and Wimbledon peaks – and the Trade Effluent Advisor

[286] Technical Director

[287] Technical Director

was after the project considering relaxing the corresponding consent limits. There are however outstanding problems with the pH levels.

The main environmental improvement of the project was the effort to recover as much as possible of the white water. The original motivation behind the investment in recovery was the income generated from selling off the re-processed milk.

The impact of the renewed regulatory pressure from Scottish Water is interesting. It generated the initiative to wash the cream tankers, which was organised outside the main investment project. The impact on the actual investment project appears to have been mainly discussions. Environmental improvement became a topic for discussion, but appears to have had little effect on the technological choices made. This was the case not least because of the timing. The main decisions were already made. The recovery as well as the automation came to be seen to be about also environmental performance, but this had little material effect on the technology.

These two technologies are cleaner technology in the sense that they reduce the effluents. But this was not part of the original motivation for investing in these measures. Environmental improvement was at first an unintentional side effect. Over the course of the project it did however come to be part of the motivation for both the recovery and the automation, but without any changes made to the technology. The technology was re-labelled as environmental, rather than re-designed.

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[288] Technical Director, Effluent Trade Advisor

Table 7.2 Decision points Dairy Scotland

Decision points	Arguments for	and against
project	*traceability, Q, RE*	
core technology		
automation and control system	traceability, Q, RE, (reg.)	
recovery	RE, revenue, (reg.)	
outside project		
cream tanker washing	reg., revenue	

Notes: 1) Abbreviations used: reg. = regulation, E = environmental, RE = resource efficiency, Q = quality.

2) '(reg.)' indicates that regulation became a motive after the main decisions were made.

Environmental improvement thus emerged as a priority rather late in the project. And this happened in spite of a formal environmental impact assessment carried out by the Technical Director.

The environmental focus in the project was also rather narrow, focussing only on the organic content of the effluent, whereas other aspects like chemicals use and the pH of the effluents, or energy use were largely ignored. It is noteworthy that the environmental management system had a broader scope including targets for, for example, energy use, but that this had little impact on the project.

The narrow focus of the environmental work in the project may be explained by the absence of SEPA regulation, and that Scottish Water's remit only includes the effluents. Scottish Water also seems to have given higher priority to reducing the organic content than to managing the pH, which corresponds well to the focus in the project on the organic content, but not the pH.[289]

The environmental organisation at Dairy Scotland is formally quite well integrated with the technical and production organisations. The Environmental Manager is however quite isolated form the technical work, in spite of reporting to the Technical

[289] Dairy Scotland has now applied for an IPPC permit from SEPA, and this may broaden the focus of the environmental work in projects at Dairy Scotland henceforth.

Director. It is not clear what impact it would have had on the project had he been involved, but one may speculate that there would have been a broader environmental focus.

8 Environmental concerns in innovation processes

We have in the previous two chapters seen cases that vary in many respects, but which have some important things in common. Firstly, they were all primarily about investments in core technology, in production process technologies like vessels and pipes, cleaning systems and control systems, although, to varying extents, the cases also included other technology, like buildings and end-of-pipe technology. This means that we are here studying investments of great importance for the core business of these companies. Secondly, we saw that regulatory demands were a central factor in terms of taking the environment into account (or not) in all the cases, (although, there were also instances of individuals promoting environmental improvements independently of regulation). These two factors, investments in core technology and the impact of environmental regulation, set up the space this chapter will analyse.

Environmental concerns were not necessarily seen as core business in these companies, but they are central to this thesis. There was in the cases a tension between the environment and core business. The discussion in this chapter will revolve around how the environment – in terms of environmental motives, work and staff – was integrated into or separated out of the core technology innovation processes studied.

The principal component of our analytical framework (as introduced in chapter 3) is the *decision-making* process. We shall discuss the relationship between motives and technological outcomes with respect to environmental performance. We need to understand how environmental motives were aligned or clashed with other motives, and who promoted what goals and agendas and why they did so, in innovation projects. Special attention will be given to any differences between the technological outcomes from projects that were and those that were not influenced by environmental motives.

We shall in the analysis focus on the roles of different *actors*, and seek to answer questions about who promotes environmental performance, why anyone would do so, and under what circumstances such promotion is successful or unsuccessful.

Special attention will be paid to the roles of engineers and environmental staff, who may influence the environmental performance in innovation work and decisions relating to technology, and their expertise and work.

The actors' behaviour is here seen as in part shaped by organisational structures, but the actors also bring their creativity as well as private life commitments to bear on their professional life. The analysis will explain the actors' behaviour as a result of the interaction between structure and action, in terms of the division and formation of expertise, career choices and opportunities and the relative status and power gained from positions on internal and external labour markets.

We shall use the concept of the *company social constitution* (see chapter 3), as a main resource for the analysis. This concept has in the past been used to discuss primarily conflicts of interest between employees and employers, although taking further actors, divisions and antagonisms into account. For the purposes of this analysis, we need to re-interpret the concept somewhat (as indicated in chapter 3) to include two different, but linked lines of conflict.

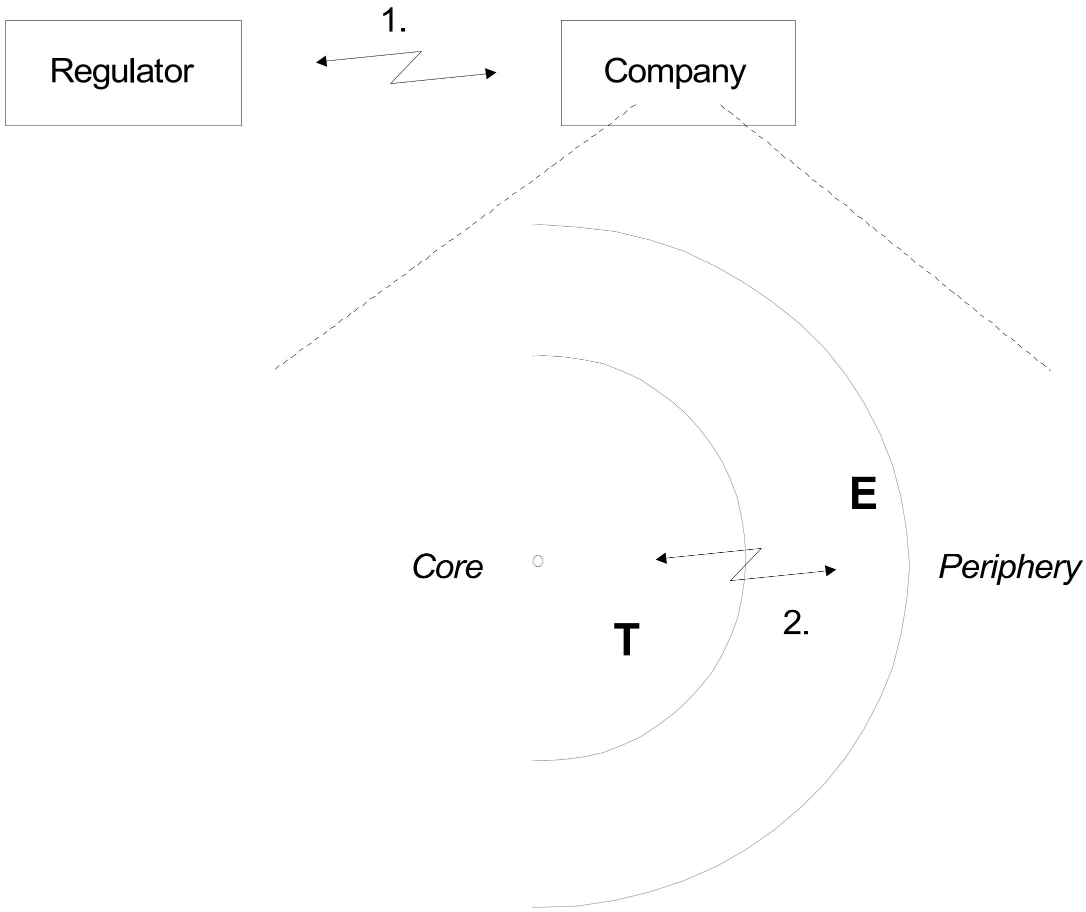
Firstly, and most obvious, there is a potential conflict between the company and the regulator (denoted 1. in figure 8.1). Here the regulator may want to see more environmental improvements than the company, and different actors in the firm may perceive regulatory requirements in different ways. The relationship between the regulator and the company – and its internal actors – forms an integral part of the company social constitution, and has consequences for the organisation of environmental and technological work.

Secondly, there is a potential line of conflict and competition in the company between groups closer to the core and those closer to the periphery (denoted 2. in figure 8.1).[290] That a group is close to the core means that it has effectively claimed the status of core competence, by successfully aligning itself with the perceived central strategies and objectives of the company. We shall here focus on the relationship between the process engineering and environmental functions, where

[290] Note that this model should not be taken to imply any *a priori* assumptions about actual conflicts in the case companies. Whether there is conflict or alignment of interests is an empirical question.

process engineers most often occupied a more central position, and distinguish between company social constitutions that contribute to linking the two groups together in collaboration, and those that instead favour separation. The company social constitution concept captures those organisational structures that contribute to the shaping of this relationship, including informal networks, routines, distributions of skills and expertise, etc.

Figure 8.1 Two linked lines of conflict



Abbreviations: T = Technology, that is, process engineering, E = Environmental function

The company social constitution is a central component of the analytical framework. The concept highlights the evolving organisational structures of the company, and how they shape decision-making. A core issue here is if and how environmental concerns come to be embedded in (or excluded from) organisational structures, routines and practices.

This analytical framework will enable us to discuss the key empricial findings of this thesis, which are:

- There was a tendency towards the separation of administrative environmental work and environmental staff from technological work, especially in cases with weak regulatory pressure. But there were also integrative social constitutions reflecting a history of stronger regulatory pressure. Environmental staff could then span the boundary between environmental and technological work, instead of merely serving as buffers between the company and the regulator.

- Apart from the systematic monitoring of project work performed by environmental staff, there were also environmental champions promoting environmental issues. Successful championing was primarily associated with a category of staff having made careers from engineering positions into management based in part on environmental merits. Organisational structures shaped both these careers and the promotion opportunities that emerged in the projects.

- The integration of environmental motives required alignment with economic motives, typically resource efficiency. Such alignment could happen *ex post*, in the form of re-interpretation of the technology without any material effects. Moreover, there are situations where cleaner technology does not offer economic advantages.

This chapter will discuss each of these three findings in the following three sections.

8.1 The integration of environmental work and staff

The empirical focus of this section is on the relationship between on the one hand environmental work and environmental staff and on the other hand technological work[291] and engineers. Regulation played a central role in this relationship. In particular, we shall show that regulation shaped the role of environmental work in relation to the investment projects studied, with weak regulatory pressure manifesting itself as a focus on administrative environmental work, carried out separately from the technological work.

Moreover, we shall show that environmental staff were the weaker part in this relationship (in general, but especially – and unsurprisingly – when it comes to technological work). But also that regulation played a central role in forming this relationship, both in terms of giving environmental staff a lever of influence over decisions made in the projects studied, and in the longer term shaping of the relationship between environmental staff and engineers. Based on these results we shall be able to propose a solution to the unresolved issue in the literature (as discussed in chapter 2) regarding whether environmental staff should be seen as a buffer against regulatory pressure or as a boundary spanner within the organisation.

We shall here use the concept of the company social constitution (CSC) to capture both the relationships between the companies and the regulators, as well as the relationships between the environmental staff and the engineers. At a more detailed level, we shall find it useful to focus on the division of expertise and on the organisational 'distance' between the actors. The division of expertise and the relative power of groups of experts will be discussed in terms of monopolies on work and knowledge in the organisations, as well as tradability on internal and external labour markets. The organisational distance will be assessed with reference to patterns of formal co-location and informal cooperation.

[291] Technological work is here used as shorthand for mainly process design work. Furthermore, the identification of technological work with engineers should not be seen as implying that they were the only ones doing such work. We shall later, for example, discuss to what extent environmental staff can be said to have done technological work. Also, one would expect production employees to involved in technological work, but that is not the focus here.

The narrative of this section moves from separation of environmental and technological work and staff towards integration, from the '*separating*' CSCs of the dairy cases towards the '*integrating*' CSCs of the chemicals cases. In the first sub-section (8.1.1) we discuss the tendency to keep administrative environmental work separate and describe the tasks on which environmental staff had a monopoly. In the following sub-section (8.1.2) we discuss the relative power of environmental staff and engineers, based on their respective monopolies on tasks and knowledge, as well as their positions on internal and external labour markets. This discussion will show that environmental staff are the weaker party of the two, and that the onus is on them to facilitate cooperation. In the last subsection (8.1.3.) we discuss how regulatory pressure could give environmental staff a level of influence over technology, depending on the integrative organisational structures that may develop over time in companies exposed to strong regulatory pressure. We here contrast formal co-location with informal collaborative structures, to shed light on the important informal integrative mechanisms present in, mainly, the chemicals cases.

8.1.1 Separate environmental work

Weak regulatory pressure tended to lead to a separation of environmental work from the technological in the projects, and a focus on administrative environmental tasks. This happened in the dairy cases, where the regulatory pressure was weaker. Dairy Scotland represents an extreme case in that no environmental work was done in the project, and that the one full time environmental staff member had no role in the project, corresponding to the absence of any environmental permit.

But even in the Dairy Sweden case, where there was an environmental permit, environmental work and staff were to a large extent separated from the technological work in the projects. The focus here was instead on administrative work, in terms of for example reporting back to the regulator. As we saw previously, the municipality environmental inspector expressed her satisfaction with the orderly environmental administrative work of the company, including their environmental management system. Even the environmental technology review mandated by the environmental permit in this case, was separated from the project, and done for the sake of keeping the regulator happy.

There was a connection in the Dairy Sweden case between environmental work and staff and the project. The local Environmental Coordinator sat in on project meetings, monitoring the technological work for permit implications, but this had little effect on the choices made, confirming the weak regulatory pressure.

The overall effect of the permit was to generate administrative environmental work, which related to – but was kept separate from – the project. The environmental staff were here limited to a buffer role, keeping the regulator happy, leaving the rest of the staff to get on with the project.

In this situation, environmental staff have no obvious need for engaging with on-going technological work (and as we shall see later, they may not get the opportunity to do so). Their more immediate concerns are to provide the permit applications, reports etc. required by the regulator, whilst on behalf of the company making sure that regulation does not become a problem, for example that the requisite permits are in place. This also involves negotiations with the regulator (and here engineers may get involved, providing local, technical expertise) regarding permit requirements.

There is here a tension in the role of environmental staff. On the one hand they represent the company interest in keeping the regulator happy and staving off any difficult or costly permit requirements. On the other hand environmental staff may have an interest in raising the profile and urgency of environmental work in the company, and one way of doing this is to have more stringent permits.[292] Either way, environmental staff had a monopoly on permit-generated administrative work, and in the short term this is enough to keep the job, and does not require environmental staff to engage with technological work.

Apart from this regulation-generated administrative work, the main task of environmental staff in the companies was to manage the formal environmental

[292] One would therefore expect higher level managers to also be involved in negotiations of new permits, controlling any such tendencies of environmental staff.

managements systems. In no case, however, did the environmental management system have a direct impact on the projects[293], which further illustrates the separation of environmental and technological work.

This separation of environmental work mirrors a separation of environmental and technological work in the companies in general. Table 8.1 lists the core tasks of the environmental staff in the cases.

Table 8.1 Core tasks of environmental staff

Work directly related to regulation
- Applying for permits - Reporting to regulators - Liaising with regulators
Environmental management work
- Participating in or leading environmental steering groups - Managing the environmental organisation - Educating employees - Environmental auditing

What is not clear from this table is how little technology-related work the environmental staff were doing. Table 8.2 lists the main technology-related tasks mentioned by the environmental staff interviewees. This includes the monitoring of project work mentioned above, and to which we shall return later when discussing the role of environmental staff in the chemicals cases were the regulatory pressure was stronger. The table also includes engineering/science-type work, which was done by very few of the environmental staff members interviewed.

[293] No interviewee referred to formal environmental management systems to explain the decisions made regarding technology.

Table 8.2 Technological work of environmental staff

Technological work
- Setting up routines (project handbooks etc.)
- Monitoring project work for permit implications
- Engineering/science type tasks: design work, literature studies, lab work

We can conclude that in cases with a low regulatory pressure there is a tendency towards the separation of environmental work and staff from technology. The focus of their work is instead on administrative work generated by the regulatory permits, and on environmental management systems, which were also largely disconnected from technological work. Administrative environmental work is in this sense a means for the company to present itself to the regulator in a way that does not open up any negotiations about its technology. This role fits well with the notion that the environmental function is mainly a buffer between the company and the regulator.

In this role environmental staff has little immediate need for cooperation with the engineers. There may however be situations in which environmental staff have opportunities to expand their remit and engage with technological work. We shall later see how strong regulatory pressure could change the role of environmental staff. But first, we shall analyse the relative power of environmental staff and engineers in the companies.

8.1.2 The relative power of environmental staff and engineers

Environmental staff were relatively weak players in the firm, having limited monopolies on work and knowledge, and thus rather circumscribed expertise. Whilst having moderately good opportunities on external labour markets, they also had, as compared to most of the engineers, less well protected local expertise. This was mirrored by an oftentimes asymmetrical relationship between environmental staff and engineers, with the onus on environmental staff to adapt and facilitate cooperation.

This section will discuss the relative power of the environmental staff and the engineers, based on the status of each group's expertise, using the model introduced in the theory chapter of the tradeability of expertise on internal and external labour markets. This will be followed by an introductory discussion of the impact of the power asymmetry on the relationship between the two categories of staff. This theme will be further elaborated in the next section.

In terms of work tasks, environmental staff had a monopoly on the kind of administrative, regulation-generated environmental work described above, as well as the day-to-day running of the formal environmental management systems. This task monopoly did not, however, translate into any monopoly on knowledge about the environmental performance of the plants. Most environmental staff did have some such knowledge[294], but as the conflict about the vent gases[295] at Chemicals Sweden shows, also engineers and production staff claimed knowledge about the environmental performance based on their knowledge of the underlying production process. It was also the case that most of the environmental staff[296] were not involved in day-to-day measurements of effluents and waste, which could have provided them with a basis for claiming expertise regarding environmental performance. The expertise of environmental staff thus has a central administrative or procedural component, relating to permits, the environmental management system etc., whilst most environmental staff appear to have less recognised expertise regarding how to achieve substantive change to the company's environmental performance.

Many (4 out of 8) environmental staff also had some environmental education. (All apart from one if we include courses in biology and energy). This contributed to the second main component of their expertise, which we may label 'environmental expertise', and which includes some scientific understanding of environmental

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[294] The Environmental Manager at Dairy Scotland is an extreme case in that he in fact had little knowledge about environmental performance of the plant in questions. This is presumably mainly explained by the absence of a permit in this case, and there thus being no requirement that he collate environmental data.

[295] About how serious the problem with the vent gases were and whether to invest in treatment of them.

[296] A clear exception would be the Environmental Technology Advisor at Chemicals Scotland. He could, in fact be classified both as engineer and as environmental staff.

impacts as well as knowledge about environmental policy. This environmental expertise also contributed to them performing their regulation-related work.

From this it follows that the core expertise of environmental staff is to a substantive degree 'occupational' rather than local and organisational (Williams and Procter, 1998:201).[297] Both the administrative-procedural expertise, and the environmental expertise are to large degrees not specific to the particular company. This expertise contributes to the external tradability of environmental staff.

All the environmental staff, however, also had some local, organisational experience. Either from long service in environmental positions (3 out of 8) or from having been recruited from other parts of the company (5 out of 8), mainly production. This testifies to the companies valuing their local experience.

Through their work with the formal environmental organisation, they are also in contact with people and the work of many parts of the company (or site, depending on their remit) operations. Some were appreciated for their experience, and well-integrated into company networks (including technology-related ones – we shall discuss this more in the next sub-section). Nevertheless, environmental staff had little company-specific knowledge that no one else had, that is, no monopoly on any local, organisational knowledge.

The backgrounds of the environmental staff point towards high entry thresholds, in the sense that all had university-level degrees. However, as mentioned only half of them had any environmental education, and in few cases full environmental degrees. It was rather the case that their formal environmental training, if any, was bundled with engineering or science expertise. And, as we saw in chapter 5, there is less well-developed occupational protection for 'industrial environmental staff' than for engineers. Whilst there is a clear occupational element to the expertise of environmental staff, it is weakly protected. Those environmental staff having external career backgrounds had held jobs in diverse sectors, testifying to the

[297] The notions of 'local' and 'organisational' expertise are here taken to be synonymous, that is, referring to expertise relating to the particular company and/or site.

tradeability of their occupational expertise, and to moderately good opportunities on external labour markets.

The promotion opportunities for environmental staff on internal labour markets are unclear. There were some senior environmental specialist positions in the companies[298], but very few environmental line management positions. An exception was the SHE Manager at Chemicals Sweden. In fact, most line managers with environmental responsibilities were in these cases technical managers with an added-on environmental responsibility (rather than the other way around).

There are thus indications that environmental staff have limited career opportunities in the environmental area, but there might be career opportunities in other areas like quality or perhaps health and safety. For example, the new site environmental coordinator at Dairy Sweden worked half time with quality.

We shall now turn to the engineers, and shall later be able to compare the two categories. The core expertise of the engineers was design (and maintenance), on which they had an internal monopoly (although in most cases competing with consultants). The engineers were also involved in project management and liaison with, mainly, production.

The engineers had a distinct local, company-specific component to their expertise. This is supported by them having the explicit role in the projects of bringing in their local knowledge (and retaining project experience for the line organisation after the projects), in those cases where consultants were used.

If we look at the career backgrounds of the engineers, those that had held other engineering jobs had done so in other process industries (pharmaceuticals, pulp and paper etc.). There is thus a sectoral component to their expertise (Fincham *et al.* 2005:3), which would appear to be less local and specific than local knowledge, but less generic than occupational expertise.

The Swedish engineers all had degrees in engineering fields (mainly mechanical, process and IT). In the UK this was replaced or complemented by certificates and

[298] Apart from Dairy Scotland with only one, junior environmental staff member.

membership of professional bodies. The engineers thus had well-developed occupational expertise, backing up good opportunities on external labour markets.

There were also relatively good internal career opportunities in some of the companies. At Dairy Sweden and Chemicals Scotland, which had large numbers of engineers employed, there were also engineers in both senior specialist positions and in line management positions (technology management mainly, but also for example production).

There were, however, large differences between the companies in terms of the engineers' internal career opportunities. In both the Swedish cases there had been efforts to reduce the number of in-house engineers. At Chemicals Sweden the maintenance function was largely outsourced and for process engineering the company relied heavily on consultants, leaving a small number (2-3 each) of maintenance and process engineers at the site (and any central engineering resources were not available for local use). At Dairy Sweden there were a fair number of local engineers (approximately 15), but the central engineering function had been spun off, but subsequently re-built. Dairy Sweden was at the time of the project back at a 'full' complement of engineers both locally and centrally. Chemicals Scotland was the company with the largest number of in-house engineers, with a large process technology department (and a separate maintenance function), the size of which was boosted by them having merged process and product development. At Dairy Sweden there were 3 central engineers, and some maintenance capacity at site level. There were, however, plans to hire more process engineers and to place them at site level.

We thus have Chemicals Scotland and Dairy Sweden with large numbers of engineering positions, both at site and central level, offering good career opportunities, both as specialists and in technology management. At the other extreme is Chemicals Sweden, with sustained efforts of keeping in-house engineering numbers down, and few opportunities within the technology area. Finally, we have Dairy Scotland with very few engineers (but possibly increasing opportunities, at least at site-level, if recruitment plans go ahead), who also had problems in the relationship with the supplier due to the lack of internal engineering capacity.

Table 8.3 summarises the power of engineers and environmental staff as based on their internal and external labour markets. The engineers have a stronger position on external labour markets based on a more distinct, and better protected occupational expertise. (Unlike environmental staff their external labour market has a strong sectoral slant.) The position on internal labour markets varies for the engineers, but there is a need for the local technological knowledge of the in-house engineers making it difficult to do without at least a small number of them, and to replace them. The environmental staff had less well-protected local expertise.[299]

This asymmetry in tradeability contributed to making environmental staff the weaker party in the relationship between environmental staff and engineers. If and when environmental staff transcend their role as buffers against the regulator, and start cooperating with other actors in the company, the relationship with engineers becomes important. Several of the environmental staff commented on the importance of a good working relationship with the engineers for their work.

Table 8.3 Tradability of environmental staff (E) and engineering (T) expertise

Labour markets / type of expertise	**Less protected expertise / undeveloped labour market**	**Well-protected expertise / developed labour market**
External / occupational	E	T
External / sectoral		T
Internal / local	E? <--- T --->	

Especially, of course, if environmental staff want to influence technological choices this relationship becomes crucial. For example, the alliance between the environmental staff and the local engineers at Chemical Sweden in the vent gas conflict testifies to the importance of the relationship with engineers for

[299] This glosses over some variation. There were a few (3) environmental staff with more formidable formal environmental qualifications and/or long in-house experience.

environmental staff to influence technology decisions. But this is also a matter of raising the profile of environmental staff in the companies. Environmental staff may well welcome a broader interest in and a higher level of concern for environmental issues in the company, making their expertise be in higher demand. This would entail leaving the relative security of administrative work, and engaging with a broader range of firm actors, including engineers.

When the two spheres of environmental and technological work did meet, the onus, however, was often on environmental staff to adapt and to facilitate cooperation. The environmental staff were dependent on the engineers, rather than the other way around.

On the most concrete level, the environmental staff sometimes had a role of being internal consultants, contributing their expertise at the demand of the engineers (or others). As we saw in the cases, environmental staff were rarely involved in the early stages of project planning, even though important decisions relating to environmental performance were made at this stage.[300] The demand for their services was then missing, and they had little possibility of negotiating access for themselves and their expertise.

A further indication is given by the educational backgrounds. Half of the environmental staff had engineering degrees (and some of them had worked in production), whereas only a small minority of the engineers had any environmental education. This engineering knowledge was useful to the environmental staff when cooperating with the engineers, but it was clearly up to the environmental staff to provide such 'interactional expertise' (Collins and Evans 2002:244).

The importance of environmental staff adapting to the engineers can be illustrated with the following quote. The current Environmental Coordinator at Dairy Sweden said in the context of collaborating with the project engineers: "*it's important with good relations with the technology side. It becomes hard work otherwise. The thing is to not be a too rigid greenie, but to be able to see things holistically*".

[300] There were some minor exceptions to this, mainly in the chemicals cases, as will be discussed later.

We have here seen how environmental staff were the weaker party in comparison with engineers in terms of monopolies over work and knowledge, as well as on internal and external labour markets. Furthermore, we have see how, in relation to technological work, the environmental staff were dependent on the engineers, and that it was up to the environmental staff to adapt and facilitate cooperation. In the next sub-section we shall discuss how strong regulatory pressure impacted on this relationship.

8.1.3 Co-location vs. co-operation

There were many examples of environmental staff and engineers being located close together, but this did not mean that they were necessarily cooperating. Environmental staff were not always seen as relevant to engineering work, and the lack of cooperation was in some instances even exacerbated by active resistance to cooperation on behalf of the engineers. The company social constitution was tilted out of favour of the environmental staff.

Regulation is what brought cooperation. Regulation gave participation opportunities to environmental staff, and thus added a boundary-spanning role for them in addition to the one of being a buffer. In the longer term regulatory pressure could engender integrative organisational structures, and shift the company social constitution from separating out environmental work and staff, to a more integrating, collaborative mode. The remainder of this section will discuss the formal and informal organisational relationships between environmental staff and engineers, and the impact of regulation on that relationship.

The environmental staff were organised differently in the case companies, both in terms of their distribution across the site and central levels as well as with which other functions they were co-organised. Table 8.4 lists the other functions with which environmental staff were organised at local and central levels. Note that environmental staff were also sometimes distributed across several functions at the same level.

This distribution means that the environmental staff were spread out with few staff in any particular organisational location. Each symbol in table 8.4 represents between one (or a half even, for half-time jobs) and three environmental staff members. And, further, that there were few examples of organisational units comprising only environmental staff.

The table also gives an indication of the complex relations between the environmental function and other functions: process engineering, production and health and safety. (There was also a relationship between the environmental function and the quality function in the dairy cases, but it played little role in the case studies, and mainly concerned the periods before or after the projects studied).

Table 8.4 Organisational distribution of environmental staff

	Site	Central
Chemicals Scotland	T, P [1)]	H&S
Chemicals Sweden	P, H&S	
Dairy Sweden	T	E
Dairy Scotland		T

Abbreviations: T=process engineering, P=production, H&S=health and safety, E='pure' environmental unit

Notes: 1) The distinction between the site and central levels breaks down at Chemicals Scotland, since some of the organisationally central staff were physically located at the site. Effectively there were site, central and site/central environmental staff.

A few patterns stand out in terms of co-location. In particular, in all cases, apart from Chemicals Sweden, some of the environmental staff were co-located with process engineers.

In the chemicals cases, some environmental staff were also co-located[301] with health and safety staff. There are also more clear overlaps between these two areas in this industry than in the dairy industry. In several instances in the two chemicals case projects health and safety and environmental concerns favoured the same

[301] That is, located in the same basic, lowest level organisational unit.

technological solutions. Likewise in the chemicals cases there were some environmental staff co-located with production.

The formal co-location of environmental staff and engineers did not, however, necessarily mean close cooperation. Especially in the dairy cases the relationship was distant and even fraught. A clear case here is the Environmental Manager at Dairy Scotland, who was co-located at the central level with two engineers (process and maintenance respectively) plus the Technical Director, who also had environmental responsibility added to his remit. In spite of this, the Environmental Manager reported that he did not work much with his engineering colleagues (apart from his boss, the Technical Director), and that they showed little interest in environmental work. In the project studied the Environmental Manager ended up having no role at all (even though the Technical Director was the internal client).

In addition to such lack of interest, the relationship could even be tense. The attitude of the Technical Manager at the Dairy Sweden site illustrates this. He said that having in that position had the added environmental responsibility amounted to sitting between two chairs, both coming up with technological solutions, and scrutinising this work from an environmental perspective. He also stated that there was a large risk of the environmental work being crowded out. He clearly saw the environmental aspect as separate from and in conflict with technological work. It was for him a limitation rather than a driver. Interestingly, the Environmental Coordinator position at the Dairy Sweden site was subsequently moved to the quality function, away from the engineers.

In the dairy companies there was then a clear distance between environmental and technological work. The company social constitution in these cases consisted of an unresolved conflict of interest regarding cooperation between environmental staff and the engineers, and an asymmetrical relationship meaning that the engineers could ignore the environmental staff, or, as in the Dairy Sweden case, even keep them away from their own work.

The presence of environmental permits integrated environmental staff into the projects. In the cases with environmental permits (all apart from Dairy Scotland), some environmental staff had the role of monitoring the projects for permit implications. This role involved sitting in on project meetings and discussing design proposals. This monitoring role did not mean that environmental staff had much influence over the decisions though. At Dairy Sweden very few concessions were made to regulatory requirements. As we saw above, the focus here was mainly on administrative environmental work, done separately from the project.

In the chemicals cases, the regulatory pressure was stronger, and regulatory requirements had to be taken into account. This gave the environmental staff monitoring the projects more influence. The environmental engineer at Chemicals Sweden explained, speaking of cooperating with the engineers in projects:

> *But then you talk about it and discuss the preconditions and demands and then you reach a good solution together. So that everyone can sigh a bit. But I thought it was really good: if it is a demand from the authorities it's not a problem.*

The monitoring role was not so much about coming up with technological solutions as about defining what the problem was. It was about translating between proposed design solutions and permit requirements (or at least making sure that that translation occurred). This is further illustrated by the vent gas conflict at Chemicals Sweden. The conflict there was about the actual environmental performance of the plant, and thus about whether there was a need for the vent gas treatment, that is, whether there was a problem to be solved. Any direct influence of environmental staff in this monitoring role was on problem definition, and so indirectly on the technological solutions by changing the criteria used to judge proposed designs.

In the Chemicals Scotland case, the environmental staff were well represented in the project and had an active role. Apart from the site Environmental Advisor monitoring the project, the senior Environmental Technology Advisor led the SHE studies starting at a relatively early stage, and was also involved in working out the solutions to, for example, the problem with the toxic effluent.

Regulatory pressure thus enabled a boundary-spanner role for the environmental staff in relation to technology. This did not mean that they abandoned the administrative tasks, but, rather than only being the buffer between the company and the regulator, the environmental staff were now also able to contribute their expertise in the projects.

In the short term, environmental permits meant that environmental staff could take on a monitoring role, and in cases with stronger regulatory pressure, environmental staff had some influence. In the chemicals cases, which had a history of stronger regulatory pressure than the dairy cases, the companies had also developed organisational structures that helped integrate environmental and technological work and staff.

The by far clearest example of this was Chemicals Scotland who had a well-established routine for scrutinising design proposals at an early stage of a project from an environmental point of view. The company also had a member of staff specialised in the environmental aspects of the company's technology – the Environmental Technology Advisor. He was in fact the only interviewee who should be classified both as engineer and as environmental staff.[302] Furthermore, there was a well-developed environmental-technological network in the company dealing on a daily basis with environmental aspects of technology, involving the Technical Director, the Environmental Technology Advisor and the Site Environmental Advisor. At Chemicals Sweden there were similar networks. But the smaller number of in-house engineers limited the company's possibilities of setting up specialised environmental-technological staff and routines.

A history of regulatory pressure also opened up career opportunities for engineers doing environmental work, producing managers with an engineering background and some environmental skills. We shall discuss this issue more in the next section.

We may note that having large numbers of in-house engineers helps create these integrative structures. Both in terms of specialisation among the engineers, but also in terms of building a working relationship between environmental staff and the engineers. Some of the environmental staff commented on preferring in-house engineers to consultants for this reason. Environmental staff with an engineering

[302] There were other environmental staff with engineering backgrounds, or called environmental engineer, but the environmental technology specialist was the only one doing much engineering-type work.

background, and the contacts developed by environmental staff in running the environmental management systems would also appear to favour such relationships. At the end of the day, however, it was regulatory pressure that brought cooperation.

We have seen how with regulatory pressure applied over time, the company social constitution can resolve the conflict between environmental staff and engineers regarding cooperation, and become manifest in integrative organisational structures. In the chemicals cases the company social constitution favoured cooperation, and environmental staff and work were better integrated, rather than separated out as in the dairy cases.

We should note, however, that such a development from a '*separating*' towards a more '*integrating*' constitution is not irreversible (as implied by the environmental determinist literature discussed in chapter 2). The interviewees at Chemicals Scotland pointed towards a somewhat weakening regulatory pressure, and a worse financial situation with the current investment company owners, threatening the environmental ambitions, and thus the environmental-technological structures still in place. Furthermore, the environmental management system at Dairy Sweden fell apart (after the project studied here) when the then Environmental Coordinator resigned. Given the less integrated organisational structure at this company, this had less impact on technological work, but the preconditions for integration got even worse.

A final comment is worth making about the role of environmental management systems. In themselves they had little impact on the projects, or on cooperation between environmental staff and engineers. Nor did the mere mentioning of environmental issues in formal technology management systems (project handbooks and the like) have any great impact. It was regulatory pressure that brought environmental considerations into play, via for example more elaborate environmental-technological routines, like the SHE studies at Chemicals Scotland.

To conclude, we have seen how the company social constitution may change to a more cooperative mode over time given regulatory pressure. This enabled a boundary-spanning role for the environmental staff, who got to contribute their expertise, and influence technological work. In either role, as buffers or as boundary spanners, the work of environmental staff was tied up with regulation. Regulation was the main lever of influence for the environmental staff, and the main legitimator of their expertise.

8.2 The formation of environmental championing

In the previous section we saw that environmental staff had a role (in companies with an environmental permit) in monitoring the technological work in the projects for permit implications, but they were not the only ones promoting improved environmental performance. This systematic promotion of environmental issues can be contrasted with more contingent environmental championing performed by other staff in some of the cases.

We have two examples of successful championing, both from Sweden. In both, the internal clients successfully promoted environmental performance. At Dairy Sweden this was the Technical Director making sure that the planned oil-fuelled boiler was replaced with district heating, and at Chemicals Sweden it was the Plant Manager who made sure to include the vent gas treatment in the main investment project, rather than treat it as a separate, permit-driven project, in the hope of finding a cleaner technology solution.

In this section we shall discuss these environmental champions in terms of what they achieved, and seek to provide an explanation for this that is sensitive to both structure and action aspects. We shall thus avoid an essentialist analysis of environmental champions (which as we saw in chapter 2 is common in the literature), whilst also avoiding making them structurally determined ‘dupes’. Empirically, this will be achieved through investigating both the – private, career and positional – interests of the environmental champions, and the structurally shaped opportunities given to them in the projects, as well as earlier during their careers.

8.2.1 Environmental merits in engineers' careers

We have earlier described environmental and engineering work as to a large extent separate (with the Environmental Technology Advisor at Chemicals Scotland as a notable exception). And whilst it is true that the engineers did little environmental work in the projects, or in general, there were also examples of engineers who had benefited previously in their careers from doing environmentally motivated work, and developed hybrid environmental and technological expertise.

We have one example from each company of people with engineering degrees who had started off in engineering positions and had made careers into management in part based on environmental merits. They are listed in table 8.5.We here have three Technical Directors, all of which had an added on responsibility for environmental affairs. Three of the four were also the internal clients to the projects studied.

Table 8.5 Managers with engineering backgrounds having benefited from environmental merits

	Position	**Project role**
Chemicals Sweden	Plant Manager	Internal client
Dairy Sweden	Technical Director	Internal client
Dairy Scotland	Technical Director	Internal client
Chemicals Scotland	Technical Director	(Unclear)

These four managers highlighted that having done environmental work in the past had contributed to their careers. The environmental merits[303] mentioned are listed in table 8.6. Apart from technical work, their merits also included managerial (apart from technology management) and administrative tasks. Some of this work overlaps with environmental staff tasks, but was for each person combined with environmental merits of the technology type. These individuals had bundled some environmental skills with their technical and managerial skills.

[303] By 'merit' we do not mean an inherent quality, but a recognised achievement.

Table 8.6 Environmental merits

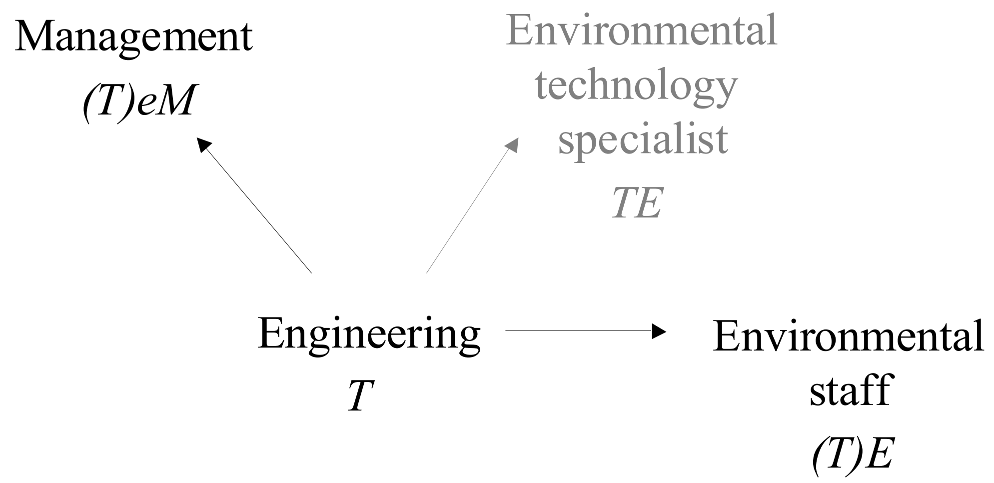
Type of work	In more detail
Technology	Managing environmentally motivated investment projects Managing operations and maintenance of end-of-pipe utilities Environmental lab-work
Management	Establishing environmental management systems Building up environmental staff capacity
Administrative	Applying for permits etc.

This was not the only 'environmental career path' open to engineers, however. As mentioned before, there were also engineers who had moved into full time environmental staff positions (indeed this was a relatively common background among environmental staff). We should also note the one example of the senior environmental technology specialist at Chemicals Scotland. These three environmental career paths are visualised in figure 8.2.

All three career paths represent formation of hybrid expertise, that is, people developing bundled expertise across traditional knowledge boundaries (Fincham *et al*. 1994:22). The management path is here the least environmental one, in the sense of doing some environmental work, but not full time. It was a matter of adding another, secondary skill (denoted by a small letter in figure 8.2), rather than full specialisation on environmental (or environmental and technological) work. A full combination, or hybrid, of actively used environmental and technological skills was unusual (as denoted by the grey environmental technology specialist path in the figure).

There were, as we have seen, some possibilities for engineers of picking up environmental merits in engineering, but also perhaps via a period in an environmental position (one or two cases in the data), for a future management career. There is, however, a risk for an engineer of staying too long in an environmental position. As we have seen environmental staff do little technological work, and there is a risk that his or her engineering skills will not be maintained and up-dated due to lack of use. This in turn may be detrimental for opportunities of going back to engineering, and into technology management positions.

Figure 8.2 Environmental career paths and skills combinations for engineers



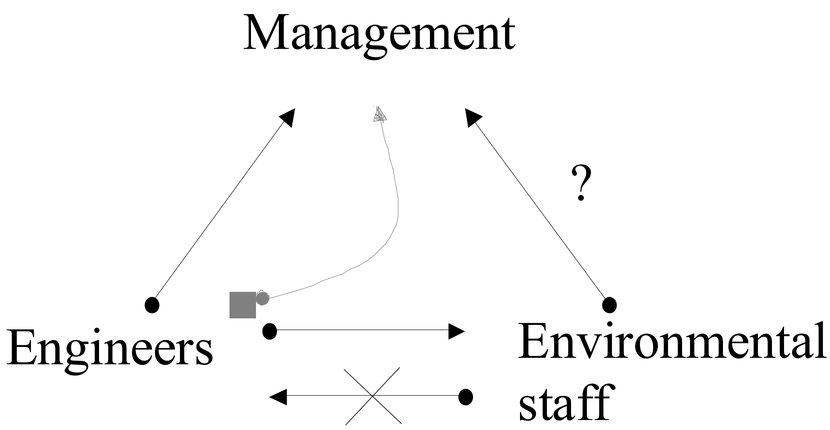
Notes: Abbreviations used: T=Engineering, E=Environmental, M=Managerial.

Small letters indicate secondary skills, and letters in parenthesis indicate skills once possessed and currently at least at risk of not being updated and maintained due to lack of use.

The grey path indicates that this was uncommon – only one example in the data.

Figure 8.3 shows this possible path via an environmental position. It also illustrates that no interviewees started off in the environmental area and moved into engineering. This certainly limited their possibilities for a technology management career, and – as we saw earlier – senior environmental responsibilities were often held by technical managers limiting the line management careers in the environmental area. (There could, however, be line management career paths for environmental staff via other areas, for example quality, but given the selection of interviewees in this study we do not know).

Figure 8.3 Engineering and environmental career paths



Notes: Dots and arrows indicate start and end points respectively. Grey, again, denotes that this career path was unusual.

The motivations mentioned by the former engineers going for these environmental career paths reveal some important things regarding the internal labour markets. For some it was just another job that came along. This was the case, for example, for the Site Environmental Advisor at Chemicals Scotland (who, interestingly, got his job based solely on his good relationship with regulator staff from previous work, and who said he had very little environmental knowledge).

In contrast, for some, it was a matter of being attracted to environmental issues as a 'hot topic'. They hoped to further their careers by achieving results in an area were they could be expected to be highly visible. This happened in the dairy industry in the 1990s, but earlier in the chemicals industry, reflecting that sector's longer history of regulatory pressure. This motivation was mainly mentioned by some of those engineers going for a management career.

For some it was also a matter of aligning private life environmental interests with their professional lives. This was mentioned by some of those going for environmental staff jobs, sometimes mentioning in the same breath the career penalties such a move brought in terms of for example salary, as evidence that they were motivated by private interests rather than by furthering their careers.

Also some of the engineers going for ‘green’ management careers mentioned private life environmental commitments as a contributory reason for their career choices. Whatever their motivations, private life and/or career interests, these management careers with an environmental element brought them into good positions to champion environmental performance in the projects studied.

We have in this section seen different examples of environmental-technological careers, that is, people bundling engineering and environmental skills into different combinations of hybrid expertise. The two main such career paths led from engineering to an environmental staff position, and from engineering to management (in at least one case via an environmental staff position). In the case studies the latter careers had (in 3 cases) led to the position of Technical Director with an added on environmental responsibility, and the managers were (in 3 cases) the internal clients of the project. Having the experience of being rewarded in their careers for doing environmental work, they were now in a good position to influence the projects and champion environmental issues. Some of them did, as we shall see in the next sub-section.

8.2.2 Structured opportunities of championing

As we saw in table 8.5 the internal customers in three out of the four cases had made such careers. Their position in management enabled them to take on the internal client role in the projects, which was arguably a relatively powerful one. The internal customers were involved in early stage planning of the projects, and approved any later changes to them (or led steering groups who made such decisions). This gave them some leeway in terms of making decisions promoting environmental performance. As we mentioned above, the two internal clients in the Swedish cases took this opportunity.

These opportunities were shaped by the company agendas. In the Chemicals Sweden case the inclusion of vent gas treatment in the project was motivated by the win-win argument that expected resource efficiency gains would make the costly end-of-pipe treatment redundant, which is well in line with the general emphasis on explicit win-win solutions in this project. In the Dairy Sweden case the district heating solution was not only environmentally beneficial, but also cheaper than the proposed new boiler, according to the Technical Director. Virtually no extra costs were accepted in this project for the sake of environmental performance improvement. The championing opportunities available were thus shaped by the company agendas, but the champions did also have an impact, and were successful in contributing to improving environmental performance.

We need to account also for the other two potential champions. In the Chemicals Scotland case the Technical Director was not given the internal client role, and so had less influence on the project.[304]

In the Dairy Scotland case the Technical Director, who like the others with this title had an added-on environmental responsibility, did not use his internal client role to promote environmental performance in the project. Contributing factors to this were the low environmental ambition level in the company and the absence of an environmental permit. We can also note that he did not express any strong private life environmental commitments, and the low priority given to environmental performance in the company meant that there were no rewards for environmental initiatives. Table 8.7 shows the pattern of factors that distinguished this case from the two Swedish ones, and explains the absence of championing in the Dairy Scotland case.

We have here seen that the championing of environmental performance in the cases had an impact on the project outcomes. The discussion has further shown that this was done by managers in the internal client role, which gave them a relatively large influence over the projects, although the opportunities for environmental championing were still shaped and limited by the company agenda. Also, these managers had started their careers as engineers and benefited from environmental merits in their careers. They had thus had career reasons for bundling environmental

[304] It is unclear what his role was in the project if any. He was however part of the environmental-technological network, in which other members contributed to ensure compliance.

skills with their technological and managerial skills. Private life environmental commitments also played a role in motivating them to take championing initiatives.

Table 8.7 Factors explaining championing

	Permit	Environment a priority	Private commitment
Dairy Scotland	No	No	No
Dairy Sweden	Yes	No	Yes
Chemicals Sweden	Yes	Yes	Yes

As compared to those engineers who took the plunge into full-time environmental staff positions, these managers stayed firmly within the core business part of the companies. That way they were rewarded with both clearer career prospects and opportunities (although contingent and intermittent) to promote environmental performance.

In terms of how to theoretically understand champions, we can thus conclude that championing behaviour is shaped both by the individual's own career and private life interests and the structured company context. The context mattered both for the current championing instances, and over time, by producing managers with bundled environmental and technological skills. To avoid essentialism we should talk of potential environmental champions, who given the right opportunity may engage in environmental championing as a behaviour, rather than calling some people environmental champions irrespective of the structured context in which they act.

We may now also add the production of potential champions to the integrative structures the company social constitution may contain. Regulatory pressure shapes management career paths for engineers willing to bundle environmental skills with their technological and managerial skills, thus creating another mechanism that can contribute to bridging the gap between technological and environmental work.

8.3 The integration of environmental motives

In the previous section two sections we have seen that environmental staff monitored the projects for permit implications (when the companies had environmental permits), and that in some cases the internal clients championed environmental improvements. Whereas the environmental staff could mainly influence problem definitions that set the criteria used to judge technological proposals, the champions could also directly influence what technological solutions to choose.

In this section we shall focus on the impact of environmental motives on technological decisions. Especially we shall discuss the impact on core technology, and the relationship between environmental and the resource efficiency motives which were prominent in several cases. We shall show that the impact on core technology (when any) depended on environmental motives being aligned with other motives, notable resource efficiency ones, since otherwise environmental improvements were seen as being too expensive. But, when thus aligned, it is not clear that the environmental motives added anything, apart from a new interpretation of what the technological solution was about. When resource efficiency was seen as a problem (in economic terms), the problem was already defined and adding environmental criteria did not clearly lead to any changed priorities.

We shall also briefly discuss the end-of-pipe investments done, mainly in the chemicals cases reflecting higher regulatory pressure, and the inherently larger use of toxic chemicals in this industry. End-of-pipe ideas were integrated into the projects when there were hopes of avoiding (or at least reducing) costs through resource efficiency or the use of existing equipment. So, as for core technology, environmental motives here had to be aligned with economic motives to be integrated into the projects. When end-of-pipe solutions were costly and hard to avoid, they were organised in separate projects.

This section brings together several theoretical themes. We shall see how environmental motives needed to be aligned with other (broadly speaking economical) motives to be integrated into (core and end-of-pipe) technology decision-making. This reflected the relatively weak position the environmental function had in the companies. Furthermore, we shall discuss how the company social constitutions shaped how environmental motives could be integrated into decision-making. A separating constitution lead to environmental concerns being ignored, whereas an integrating constitution lead to integration of environmental concerns, but such motives then had to be aligned with other interests.

In this section we shall also return to the issue of how to understand the concept of 'cleaner technology'. By using an analytical framework which treats intentions (motives) separately from the technological outcomes, we shall be able to distinguish between 'unintentional', 'intentional' and 'ambitious' cleaner technology, as discussed in chapter 2.

We saw examples of unintentional cleaner technology, where environmental improvements were an unintended side effect (as in the Dairy Scotland case, until the increased regulatory pressure led to the re-interpretation of the technology), and intentional searches for cleaner technology win-win solutions (as in the Chemicals Sweden case). We did not see, however, any unambiguously ambitious cleaner technology.

8.3.1 Environmental motives in core technology decisions

We shall here summarise the role of environmental motives and their impact on the technological outcomes.[305] In the projects studied environmental motives had to – with very few exceptions – be aligned with other motives to be integrated, that is, to be part of the motives for a go-ahead decision regarding a technological solution. There were virtually no instances were environmental motives alone motivated the technological solution chosen.

With respect to core technology environmental motives were often aligned with resource efficiency motives. Other commonly aligned motives include quality and in the chemicals industry also health and safety. Where environmental motives were not

[305] The motives are listed per technological decision in tables in the discussion section of each case study.

so aligned, they were seen to be too costly. Environmental motives in those cases lost out because of (mainly) investment cost and production efficiency concerns.

We may also note that environmental motives were almost always defined by current regulation, rather than volunteered by the company itself. For example, the Technical Manager at Dairy Sweden said in response to a question about whether there were any environmental experts involved in the project: "*No. It was common sense I would say. But what we had was an environmental permit … So, that's what affected us*". The consultant project leader at Chemicals Sweden on environmental values: "*Well, values… We have the targets very clear – there's an environmental permit here"*. The Safety Engineer at the same company said about the VOC emissions after the project:

> Interviewer: *The outcome – was it too much in any sense?*
>
> Safety Engineer: *Borderline case. We don't have any direct permit conditions* [for VOCs from this particular plant on the site] *… Since this was related to an actual condition in the* [site-wide] *permit, this probably was the most critical part for* [this project].

We can here see the tension between environment and the core economical concerns. Environmental motives were not strong enough in themselves to affect decisions, and had to be aligned with more well-established core business concerns. In cases with weak regulatory pressure and separating CSCs – the dairy cases – environmental motives were not integrated. A quote from the Technical Director at Dairy Scotland illustrates this: "*it helps the environment, but it costs us less money. So, I suppose it's financially driven. That's being totally honest!*" The consultant Project Leader in the Dairy Sweden case: "*It was really a lot of heat exchange [technology] to recycle the heat. That as well is connected to costs. Even if the energy cost is a small fraction of the cost of the product it's still money*".

In cases with stronger regulatory pressure and integrating CSCs – the chemicals cases – environmental motives were integrated, and aligned with core business interests. For example, the Environmental Engineer at Chemicals Sweden said with regard to the aims of the project: "*it was about achieving better quality, better* *environmental performance, better safety and more product and better profitability, with a modern plant*".

It is also worth noticing the virtual absence of voluntary environmental action, and the lack of pro-activity. This is notable given the attention in literature to these drivers (Aragón-Correa 1998; Meredith and Wolters 1994:25; Marshall *et al*. 2005), and particularly given that two of the cases are in the chemicals industry with its long history of relatively strong regulatory pressure and public scrutiny. This leads us to a certain scepticism regarding the claims made in the literature about the future of self-regulation, and also shows the value of not studying only best practice cases (compare discussion in section 4.2.2).

We have seen how environmental motives were, in the chemicals cases, aligned with core, mainly economic motives. We may now ask what the environmental motives contributed when there were also other, not least resource efficiency, motives present. This discussion will also shed new light on the concept of 'cleaner technology'.

To achieve this we may compare and contrast cases of cleaner technology innovations (as defined by the environmental outcomes).[306] Chemicals Sweden appears to provide a textbook example of cleaner technology. The piping technology introduced improved resource efficiency (and quality) as well as reduced environmental pollution. It was also a case of an intentional search for a win-win solution; both motives were present from the start. We called this scenario 'intentional cleaner technology' in the literature review. It was even the case that, to some extent, this was a choice between end-of-pipe and cleaner technology. The vent gas treatment was initially a part of the project, with the motivation that resource efficiency gains might render it unnecessary, or at least reduce its size and cost.

It is interesting to compare this case with the new control system at Dairy Scotland. This innovation did in fact improve the environmental performance, but that was not why it was initially planned. At the start of the project the control system was

[306] There were clear cases of this in all cases apart from at Chemicals Scotland where resource efficiency improvements were postponed until a later stage.

motivated by other motives: traceability, resource efficiency and quality. Only after the regulator started applying pressure half way through the project did environmental improvement become a concern. The solution was then not to change anything material about the proposed design, but to re-interpret the technology as also delivering environmental advantages. In this case, then, environmental improvement was initially just a side effect, and even an unintentional one.

We may also compare with the Dairy Sweden case where resource and cost efficiency were central motives behind the project in its entirety, and several of the suggested technological solutions, some of which were adopted. Environmental motives played little part in these decisions at the time, but the outcomes could later, in the interviews, be described as delivering environmental benefits. The Technical Director at Dairy Sweden said about the new plant:

> *I think the biggest improvement was to shut down the old site … we don't have that kind of impact here that we had in [the nearby town]. So in total we have a lesser environmental impact today. It's new technology; you discharge less. We built with new technology.*

The Environmental Coordinator at Dairy Sweden on improvements in energy consumption: "*it gets better when you construct a new plant. New, more efficient equipment*". The actors in this case may have been aware at the time of the project of the environmental side effects, but that is not clear and the point here is that such concerns played little role at the time.

The two dairy cases exemplify what we called 'unintentional cleaner technology' in the literature review, and they show that environmental motives could be attached to core technologies *ex-post* through re-interpretation of the technology. This raises questions about what happened in the Chemicals Sweden case. Did the presence of an environmental motive from the beginning in this case mean that it had more of an impact on the technological choices made, or was the environmental motive also in this case attached to the core technology without making any material changes to it because of this motive? To rephrase the question, would the piping technology have been introduced, and on the same scale, even without the environmental motive? We do not know this. The environmental motive was present, and aligned with other motives, and we can not say that it did not have an impact. However, it did not add anything independently of the other motives. It was not, therefore, an example of ‘ambitious cleaner technology’ to stick with the terminology from the literature review.

In the literature review we also raised the question about whether and how environmental motives may reinforce a search for cleaner technology initiated for other reasons (as suggested by Clayton *el al*. 1999:219). In the Chemicals Sweden case the environmental motive contributed to the decision regarding the pigging technology, but it is not clear that it makes any sense to say that it reinforced the search for cleaner technology. Reinforcement presupposes a sequence of events where the search pre-dates the addition of an environmental motive. This did not happen in the Chemicals Sweden case.

All in all there is little evidence to say that environmental motives adding anything extra to, or reinforced, searches for cleaner technology in these cases. There is no clear case where environmental motives raised the level of ambition regarding the environmental performance of core technology as compared to any pre-defined level. This is not to say that environmental motives did not matter for the technological choices made. At least in the Chemicals Sweden case this motive did matter. But it is to say that environmental motives only mattered insofar as they could be aligned with other motives. Environmental motives did not motivate any improvements to environmental performance through core technology innovations over and beyond what could be motivated also by other motives.

We have seen examples, then, of intentional and unintentional cleaner technology. This distinction also reflects the role of the actors in the projects. Resource efficiency was pushed by management, and the solutions delivered by the engineers. As we have seen the environmental staff had little effective influence in the dairy cases (none in the Dairy Scotland case). In the Chemicals Sweden case the environmental staff had some influence, in line with the stronger regulatory pressure, and the environmental benefits of the core technology innovations were in this case intentional, although not obviously ambitious. There was clearer evidence of the influence of environmental staff in the case of end-of-pipe technology, as we shall see in the next section.

8.3.2 End-of-pipe

Finally, we shall briefly discuss the end-of-pipe innovations. These mainly occurred in the chemicals industry, reflecting stronger regulatory pressure, as well as the inherently broader range of toxic chemicals used and potential ways of damaging the environment.

Proposed end-of-pipe solutions were treated as part of the main investment projects when it was possible to use existing end-of-pipe equipment as in the case of Chemicals Scotland, or when there was hope of avoiding them or at least reducing their size and cost through cleaner technology solutions as in the example of the vent gas treatment at Chemicals Sweden. When this was not the case, that is, when they generated cost and were unavoidable, as regards the other end-of-pipe investments at Chemicals Sweden, the end-of-pipe investments were 'spun-off' as separate projects. This reinforces our picture of environmental things as something to be separated from core business, unless they can be aligned with economic benefits.

The cases also shed new light on the grey zone between cleaner technology and end-of-pipe technology (note that this is an analytical grey zone and does not mean that there was necessarily a choice to be made between cleaner and end-of-pipe technology). We have in the cases seen several examples of this. There were cases of recovery – of substances from effluents and of energy – in the case studies. It could be argued that this is cleaner technology, since even though the waste is produced, it is then fed back into the processes and thus after a detour is no longer waste. Waste/pollution production is avoided.

A perhaps more interesting example is given by the nitrogen ballasts proposed in both the chemicals cases. In both cases the ballast had the potential to reduce gaseous waste flows. At Chemicals Scotland the ballast was necessary for compliance with health and safety regulation, but also to avoid explosions, and we thus have a clear case of a cleaner technology offering both environmental and technical (ultimately economic) benefits. In contrast, at Chemicals Sweden the ballast was not necessary, and would in fact have slowed production down somewhat. This lack of economic advantage makes it tempting to call it an end-of-pipe application, but since it would have caused less waste to be produced we should by rights call also this application cleaner technology. We thus have an example of cleaner technology not offering economic advantages. If nothing else this shows that we should avoid including economic advantages in the definition of the concept (for example, for McMeekin and Green, 1994:2, lowering production cost is part of what cleaner technology means). It also illustrates the difficulty of associating the concept of cleaner technology with a specific technology. Whether it is cleaner or not depends on the particularities of each application.

For the end-of-pipe investments in both Chemicals cases the environmental staff had important roles. Given what we discussed above about the lack of reinforcement, the impact of environmental staff was more distinct when it came to end-of-pipe than core technology decisions.

In this section we have discussed the integration of environmental motives into innovation processes and their impact, when any, on the technological solutions chosen. This discussion has confirmed earlier results showing that resource efficiency is an important motive behind cleaner technology innovations (Malaman 1995:2; Clayton *et al*. 1999:238). Especially in cases with weak regulatory pressure and separating CSCs, it was apparent that environmental motives are not necessary for cleaner technology solutions when resource efficiency is already a priority. This may be called unintentional cleaner technology.

We also saw that in cases with strong regulatory pressure and integrating CSCs, environmental motives were integrated into the innovation processes, and even into decisions relating to core technology, but only if they were aligned with other motives. There were, thus, examples of intentional cleaner technologies, where the project participants searched for win-win solutions, but we did not, however, see any ambitious cleaner technology where environmental motives reinforced or added anything extra to resource efficiency motivated innovations. Instead, we saw examples of technologies being flexible enough to be re-interpreted as cleaner technology, after the relevant decisions had already been made.

With this in mind, it became clear that the impact of environmental staff being present in the projects was clearer when it comes to end-of-pipe innovations. The main task of environmental staff in the projects was to monitor design proposals and ensure translation between them and regulatory requirements. In the case of end-of-pipe technology, such environmental motives clearly added something, and when unavoidable led to material changes to the technological solutions.

We have in this section been able to reach a new, more nuanced understanding of cleaner technology. A distinction has been made possible in the analysis between unintentional, intentional and ambitious cleaner technology, reflecting different ways of linking, or not, environmental motives to core technology innovations. This analysis has, in turn, been made possible through selecting not only 'best practice' cases where environmental motives are central, but also less environmentally ambitious cases.

8.4 Conclusion

We have in this chapter used the concept of the company social constitution to capture the organisational tendencies in the cases to separate or integrate environmental work, staff and motives from core technology innovation. We have seen separating constitutions in the dairy cases with weak regulatory pressure manifesting itself as a focus on permit-generated environmental work, resulting in a buffer role for environmental staff. This was contrasted with the chemicals cases with more integrating constitutions and stronger regulatory pressure. Here environmental motives played a bigger role in the projects, and environmental work and staff were more integrated into the projects. The environmental staff were then able to add a boundary-spanning role to their repertoire. This was facilitated by integrating organisational structures in the shape of environmental-technological networks and routines, built up over time in companies with a history of comparatively strong regulatory pressure.

The relatively weak power of the environmental staff as compared to the engineers made the former dependent on the latter for cooperation, and the onus was on environmental staff to facilitate cooperation. In cases with separating constitutions the engineers could to a large extent ignore environmental staff, and there were even indications of some tensions between the groups. Regulatory pressure gave environmental staff a stronger position and a lever of influence, and over time a more integrating constitution could result.

There were two main career paths during which environmental and engineering skills were bundled to form environmental-technological hybrid expertise. Firstly, engineering was a common background of environmental staff, and a help to them in facilitating cooperation with engineers. Secondly, there was a category of people who had started off as engineers, and who had made managerial careers in part thanks to environmental merits. This second career path, which stays closer to the core of the company's concerns, offered – it seems – more rewards for those pursuing it, whilst also giving them – intermittent – opportunities to champion environmental issues in innovation processes.

Environmental championing should be understood both in terms of action and structure. The potential champions acted based on their career interests as well as private life commitments, whilst also both in their past career choices and in the current situation adapting to those opportunities offered to them by the organisations. The production of such potential champions with bundled technological, environmental and managerial skills can be seen as another integrative mechanism, facilitating the effective integration of environmental motives into innovation work.

We saw that environmental motives could be integrated into core technology innovations, in cases with integrative company social constitutions, by aligning the environmental motives with other motives, especially resource efficiency. In the Chemicals Sweden case we saw this happening, and a search for win-win solutions resulted in an 'intentional cleaner technology' solution. In contrast, in cases with separating constitutions and weak regulatory pressure, environmental motives were largely absent from the innovation processes. Also in these cases cleaner technology solutions were chosen, but without environmental motives. The resulting environmental improvements were then un-planned side effects of 'unintentional cleaner technology' innovations.

Interestingly we saw that technologies could also be re-interpreted *ex-post*, that is, after the design solutions has stabilised. Environmental motives could then be 'discovered' and added to the technology, without any material changes to the design. For example in the case of the control system at Dairy Scotland, the technology was in this way flexible enough to take on this new layer of meaning. The possibility of re-interpretation raises questions about what environmental motives actually add when there are other motives for cleaner technology present. We have not seen any clear examples of 'ambitious cleaner technology', where environmental motives added something that was not motivated by for example resource efficiency concerns.

The main theoretical contributions from this analysis concern the conceptualisation and categorisation of 'cleaner technology', how to explain championing in terms of both structure and action, and the modification of the company social constitution concept to suit the case of environmental aspects of innovation. We shall discuss the theoretical implications of this study in more detail in the next chapter.

9 Conclusion

At the heart of this thesis is the fundamental issue of whether our use of technology can be made ecologically sustainable. The optimistic ecological modernisation theory has great hopes for the integration of ecological rationality and for the potential of the introduction of new technologies to reduce environmental impacts, whereas the more pessimistic green Marxism emphasises the irreconcilability of environmental and profitability concerns, and sees technology as an instrument towards the latter goal. Where ecological modernisation is somewhat vague about how ecological rationality will come to be integrated into firms, green Marxism would highlight the continued need for state intervention in the form of environmental regulation (whilst not necessarily assuming that this will be sufficient or effective).

The focus in this thesis is on questions about how and why environmental considerations impact or not on technological design choices in investment projects in process industries. From this we can see how investment projects both offer opportunities and set up constraints on the effective promotion of environmental concerns.

In the following two sections we shall sum up answers to the research questions set out in the introduction and discuss the contributions to theory of this thesis. The last two sections of this chapter will discuss the main implications of the methodological choices made, and set out issues for further research.

9.1 Empirical results

The research questions have effectively been answered in chapter 8. We shall here sum up the main points of those answers.

1. *What is the impact of environmental intentions on the technological outcomes, especially on core technologies?*

In the case of core technology, we saw that for environmental motives to be integrated into the investment projects and the core technology innovation process, they had to be aligned with other motives, most often resource efficiency motives.[307]

Such integration of environmental motives could happen both before and after the major decisions relating to the design solution had been made. In the latter case, environmental motives did not affect the technology materially, and what actually happened was a case of business-as-usual innovation, with environmental improvements being unintentional side effects. The technology was re-interpreted as being environmental, rather than being materially affected.

There were also cases of technologies being cleaner in the sense of reducing the production of pollution and waste, whilst at the same time not being economically advantageous.

2. *How do any environmental concerns that firm actors may have affect the decisions made in innovation processes?*

We have identified two categories of staff who promoted explicit environmental motives: environmental staff and environmental champions. Environmental staff had the role to monitor the projects (in cases with an environmental permit), and when the regulatory pressure was strong enough they had some influence on the technological work in ensuring that permit requirements were translated into criteria for the technological design work. They thus contributed to problem definitions rather than directly to the design of new technological solutions.

In cases with what this thesis has identified as integrating company social constitutions, environmental staff were more central to the companies. The environmental staff in these cases had a boundary-spanning role, whilst also acting as a buffer between the company and the regulator. In cases with a separating company

[307] End-of-pipe technologies could sometimes also be aligned with other motives, mainly cost savings through the use of existing equipment, and only then were they integrated into the main investment projects.

social constitution the engineers could afford to ignore the environmental staff, or even actively keep them at a distance. Strong regulatory pressure made for successful promotion in the sense of intentional searches for win-win solutions, as mediated by environmental staff in their boundary-spanning role.

Environmental champions were individuals who had accumulated experience from different areas of work. Like many of the environmental staff they had hybrid expertise encompassing engineering and environmental skills, but for these managers their environmental skills were secondary rather than primary skills. These environmental champions had career as well as private interests in doing some environmental work.

In three out of four case studies such individuals were also the internal project clients, and so had some direct influence on the decisions made. The environmental championing, however, still had to be adapted to the company context, and aligned with other motives, for example cost savings. The championing opportunities they had were thus limited and shaped by the company agenda.

3. *What are the structurally determined organisational limits and opportunities to the integration of environmental concerns into firm innovation processes?*

We have seen how engineering and environmental expertise is formed and deployed in a relatively stable matrix of conflicts of interest: the 'company social constitution'. We have further seen a difference in the company social constitutions in terms of integrating or separating environmental motives, work and staff in relation to innovation processes. A history of strong regulatory pressure could engender integrative organisational structures in terms of environmental-technological networks and routines, where otherwise these two areas of work would be kept separate.

An integrating company social constitution allowed for the integration of environmental motives into the investment projects, but only if it could be aligned with other motives. With a separating constitution environmental motives were not made part of the agenda.

It is worth noticing that the construction over time of integrative organisational structures is not an irreversible process (as implied by the environmental determinist tendency identified in the literature in chapter 2). There were cases where environmental-technological organisational structures fell apart, or were threatened by changing company fortunes.

9.2 Contributions to theory

This section will be organised around fours aspects of this research. Firstly, we shall discuss and criticize the concept of 'cleaner technology'. This is followed by theoretical contributions regarding organisational politics. Thereafter, we shall discuss the results of applying a Science and Technology Studies perspective to the topic of environmental aspects of innovations, which has been dominated by management research. Finally, we shall see what implications this study has for ecological modernisation and green Marxism.

9.2.1 'Cleaner technology'

We shall in this section argue that the notion of 'cleaner technology' (and as a consequence 'environmental innovation') is a misleading concept, for several reasons.

Firstly, as already discussed in chapter 2, cleaner technology is not a universal class of technologies, as is sometimes assumed (see for example Murphy and Gouldson 2000:36; del Río González 2005:22). Typically, clean technologies are not available off-the-shelf as 'black boxes', but rather have to be developed *in situ* to fit in with the existing plant and processes. Studying firms, we should speak of cleaner innovation rather than cleaner technology.

This also means that we should reconsider some of the arguments for why cleaner technology has not delivered on its promises. It is not because the technology is new (Malaman 1995:2), or, specifically, newer than end-of-pipe technology (Murphy and

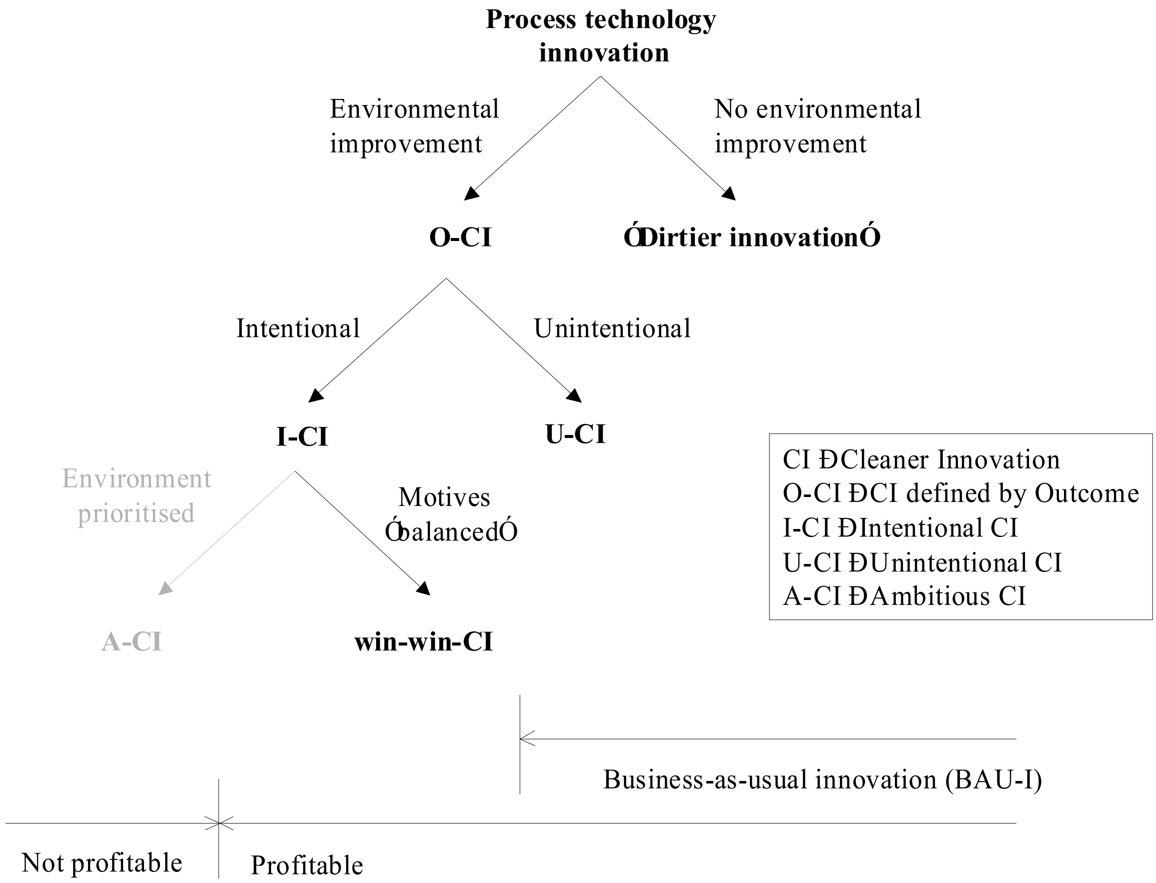
Gouldson 2000:36). The technology used for cleaner innovation does not have to be new, just more efficient than that what the company had before. Nor is it because up-take has been low (as assumed by Clayton *et al*. 1999:2). Since cleaner technology is not a (universal class of) technology, this argument is no longer relevant. The question is rather why few companies have tried to find win-win solutions. We shall return to this question later.

Secondly, the concept of ‘cleaner technology’ is ambiguous and conflates several different types of innovation. These types are different in terms of the underlying motives, the outcomes and likelihood of occurrence. Figure 9.1 shows the different cases identified.

Starting from the top we can make a first distinction between those process technology innovations that lead to environmental improvements, and those that do not. The former case corresponds to a definition of ‘cleaner technology’ by outcome (O-CI), and the latter we may by extension name ‘dirtier technology’. Thereafter, we may also make a distinction between those O-CI innovations that are the result of intentional searches for cleaner technology (I-CI) and those that are unintentional (U-CI). Here the former case corresponds to a definition of ‘cleaner technology’ by intention. Lastly, we can distinguish between cases where environmental motives are prioritised over economic ones (A-CI), and those where environmental motives are as important as (or less important than) economic motives (win-win-CI). The former case we shall here call ‘ambitious cleaner innovation’, and the latter case corresponds to intentional searches for win-win solutions.

It is worth noting here that reality may be less clear-cut than these categories indicate. If it is uncertain whether there has indeed been an environmental improvement, then the boundary between dirtier innovation and unintended cleaner innovation may be unclear. And exactly how important does the environmental intention have to be to categorise the innovation as win-win? Nevertheless this categorisation is useful for distinguishing between what are often rather different categories of innovation in terms of environmental motives and outcomes.

Figure 9.1 Different cases of 'cleaner technology' innovation



We have in our case studies seen examples of most of these categories. For example, in the Dairy Scotland case the changed cleaning routines meant more use of chemicals than before: dirtier innovation. Most of the innovations observed with beneficial environmental outcomes were driven by resource efficiency motives rather than any environmental considerations: unintentional cleaner innovation. The pigging technology at Chemicals Sweden was driven by resource efficiency, but also – to some extent – by environmental concerns: win-win cleaner innovation. We have not seen any example of ambitious cleaner innovation. If we stick to the vocabulary set out in the introduction chapter, we may now also say that business-as-usual innovation, that is, those cases without any environmental motives, includes dirtier innovation and unintentional cleaner innovation.

Most of the innovations we have studied in this thesis are unintentional cleaner innovation. This reflects the methodology used in two ways: firstly, we wanted to avoid the asymmetry of studying only 'best practice' cases, which are more likely to be cases of win-win cleaner innovation, and secondly, we selected those technological choices that had some relevance for environmental outcomes. Technologies adopted that did not make any environmental difference, for example some of the software for the control systems, are therefore less likely to have appeared in the case studies. They would here be subsumed under the 'dirtier innovation' category. But this result also reflects a reality. It is interesting that we have seen so few examples of ambitious and win-win cleaner innovation, especially since we have studied two chemicals industry cases with their comparatively more acute potential environmental impacts. We shall discuss this more below.

With this categorisation in place, we are now in a better position to discuss different definitions of 'cleaner technology'. Let us first consider definition by outcome (O-CI in figure 9.1). This definition captures all the process technology innovations that improve environmental performance, and many of those also give economic benefits. This definition thus seems to correspond well to what we have previously thought of as 'cleaner technology'.

But this category appears to be dominated by unintentional cleaner innovation, driven by resource efficiency (and other non-environmental) concerns. The technology used for such innovation is sometimes new, but only in the sense that all investments are made in established and new rather than obsolete technology. Investment in new, more efficient technology is not a new phenomenon, and we know that this has not been enough to manage the environmental problems of manufacturing industry. By this definition 'cleaner innovation' is not necessarily new, but nor has it delivered enough environmental improvement.

A further problem with this definition is that it is all too easy to apply *ex post*. As we have seen the 'environmental-ness' of the technology was sometimes a result of re-interpretation after the fact of the technology, that is, after the design choices had already been made.

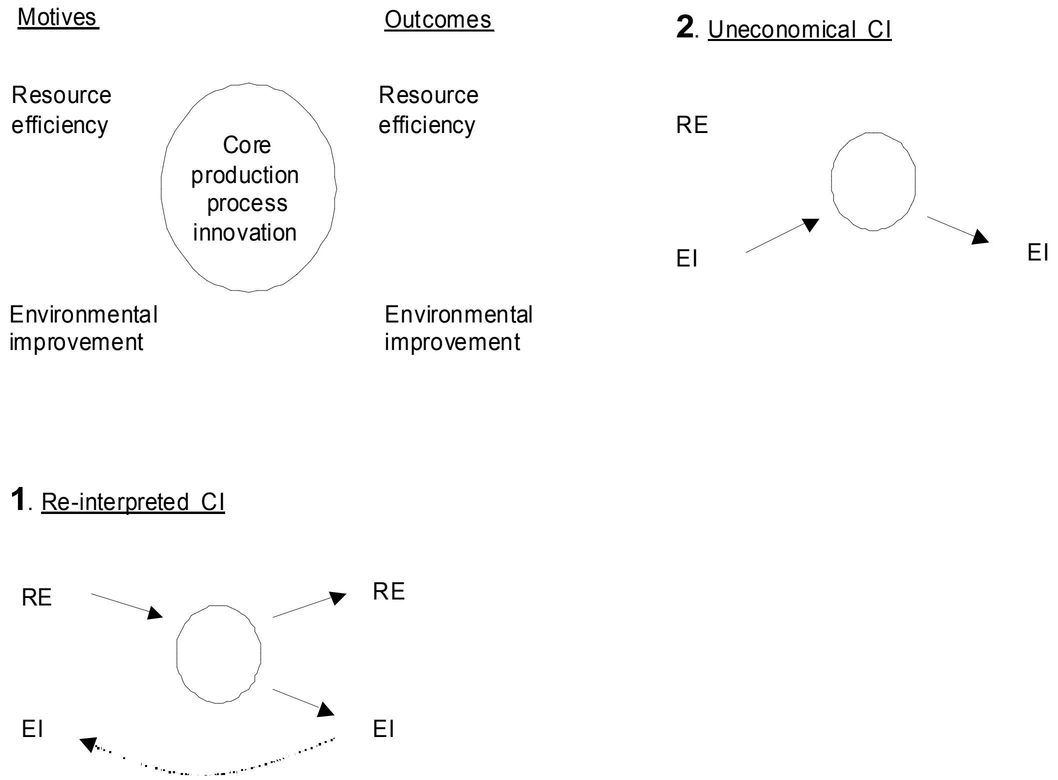
This fits well with the idea of bounded rationality. In the case of Dairy Scotland, regulatory pressure induced the company to re-frame the project in environmental terms, and to discover the environmental benefits it was getting from the technological choice it had made. (Maybe if the environmental manager had been involved in the project the company would have been aware of this earlier). The technology was in this sense flexible enough to allow this new interpretation.

But this was also a case of the company trying to 'blackbox' (Scarbrough 1995) the technology and present it as environmental as an afterthought.[308] Had it considered the environmental aspects of the technology earlier in the project, the outcome may have been different. This possibility is obscured when the label 'environmental' is attached *ex post*. This illustrates how the concept of 'cleaner technology' may reify environmental intentions, and impute such intentions where there are none. See diagram 1 in figure 9.2.

Let us now move on to the option of defining 'cleaner technology' by intention (I-CI). We have here confirmed that win-win solutions are possible. The pigging technology at Chemicals Sweden is the clearest example of this from this study. But we have also seen that intentional cleaner innovation does not necessarily offer any economic benefits. By comparing the decisions made regarding nitrogen buffers in the two chemicals cases, we may conclude that the technology would have offered environmental benefits but its reduction of production efficiency made it less appealing for the companies. In the Chemicals Sweden case the idea was abandoned for this reason, but in the Chemicals Scotland case it was adopted because of safety regulation requirements and to ensure production. In the former case there were hopes of the buffer reducing emissions, thus making it intentional cleaner innovation, had it been adopted.

[308] Note that this was not a case of blackboxing the technology as a way of commodifying it, but as a way of making the adoption of technology seem environmental. We may also say that it was blackboxing of innovation rather than blackboxing of technology.

Figure 9.2 Illustrations of some types of cleaner innovation



Note: 'RE'=resource efficiency, 'EI'=environmental improvement.

We may draw several conclusions from this. Firstly, since cleaner innovation does not always offer any economic advantages (compare McMeekin and Green 1994:2), it is inaccurate to see it as always embodying win-win solutions. See diagram 2 in figure 9.2. Again, there is reason to be wary of the blackboxing of environmental-ness. Secondly, the cases of uneconomic cleaner innovation studied (admittedly a limited number) suggest that companies do not voluntarily engage in cleaner innovation unless it also offers other, economic advantages. In this sense, environmental concerns are subordinated to economic ones.[309] It is ultimately the economic benefits of cleaner innovation that attract companies, and when it does not offer any such benefits investment will be scarce, unless compelled by regulation (compare end-of-pipe innovation).

[309] Note also that the 'opposite' case of economic considerations outweighing environmental ones does not appear to stop investment.

But if win-win cleaner innovation is possible, why has it not delivered on its promises? Some reasons for this have already been provided by Clayton *et al.* (1999). Their observation was that when resource efficiency drivers are strong and well established, there may be little difference between what can be considered cleaner technology and what is good engineering practice (*ibid.*:241). There is then little scope for environmental considerations to add anything. However, given bounded rationality, environmental considerations may reveal new opportunities to improve resource efficiency, and thus also environmental performance (*ibid.*:219), that is, what we previously called 'environmentally induced cleaner technology'. See figure 2.1. Even when there are opportunities for profitable investments improving resource efficiency, they may go unnoticed, and a lack of attention to environmental concerns may help explain why that is the case. We would propose that this is possible especially in cases where resource efficiency is a less strong driver.[310]

To sum up, the concept of 'cleaner technology' is misleading for several reasons. Firstly, it is not a universal class of technology, and it is better to speak of 'cleaner innovation' as a situated activity. With this in mind, we may conclude that cleaner innovation as an activity is not new – it is only new as an intentional approach to improving environmental performance. Furthermore, the technologies used for cleaner innovation may be new or well established ones, and the uptake of those technologies is not generally low. Cleaner innovation as an intentional approach is newer than end-of-pipe innovation, but the technologies used for cleaner innovation are not generally newer than those used for end-of-pipe innovation.

Secondly, the term conflates different cases of innovation with different motives and different outcomes. Through this ambiguity the term lends itself to reification and imputation of environmental intentions where there are none. Environmental improvements are more often the unintentional side effects of process technology

[310] We may also attempt to clarify one detail. Clayton *et al.* also claimed that environmental considerations could 'reinforce' existing, on-going searches for resource efficiency. See figure 2.1. Whilst we have not seen any clear examples of this – the pigging technology at Chemicals Sweden is the main candidate for this, but it is not clear that environmental considerations are what made the project team expand this part of the project – it seems possible that reinforcement could work though induction, and that during a search for resource efficiencies, attention to environmental performance could reveal new such opportunities. This is however speculation, and it is still unclear what 'reinforcement' means in this context.

innovation done for other reasons, than intended outcomes. The term can too easily be used to justify business-as-usual innovation, which we know is not enough.[311]

Thirdly, cleaner technology may not offer the economic advantages the term is usually understood to imply. The term ‘cleaner technology’ thus obscures the possibility of going ‘beyond win-win’ and prioritising environmental performance even at an economic cost. Such ambitious cleaner innovation is unlikely to happen without regulatory pressure, since firms subordinate environmental considerations to economic ones.[312]

We have here set out a new model for understanding the environmental dimension of core technology innovation that avoids the pitfalls of reification (taking the environmental properties of ‘cleaner’ technologies for granted) and asymmetry (explaining only ‘best practice’ innovations). This has been achieved through a more carefully drawn distinction between technology and innovation, and through analysing intentions and outcomes as distinct phenomena in innovation processes.

9.2.2 The role of organisational politics

A part of the aim of this thesis is to study the role of environmental intentions in decision-making in the context of innovation processes. We have chosen a political approach to decision-making, and in this section and the next we shall explore the role of such organisational politics.

We have used the concept of the ‘company social constitution’ to capture the organisational structures evolving around potential conflicts of interest between the company and the regulator, as well as between engineers and environmental staff. This concept has been developed to suit the topic of this thesis, and proven useful in terms of analysing the integration or separation of these actors.

[311] If it were, such voluntary action would already have solved the environmental problems, and there would have been no need for regulation.

[312] Ambitious cleaner innovation is in this sense similar to end-of-pipe innovation.

We have seen examples of championing behaviour by a category of managers. The analysis showed how we might explain this behaviour through the interaction of the structured company context and the interest-based action of these individuals, drawing on a categorisation of interests as stemming from private lives and careers as well as organisational positions. Below, we shall discuss in more detail the topics of the 'company social constitution' and 'environmental championing'.

9.2.2.1 The 'company social constitution'

The concept of the 'company social constitution' has in the past been used to theorise mainly the conflict of interest between employers and employees/workers (for example, Koch 1997 and Kamp 2000). It has been given the meaning of those organisational arrangements and structures generated by these actors' behaviour relating to this conflict. Since we have applied the concept here to a somewhat different topic, it has been necessary to adapt and develop it, but we have also been able to criticise earlier versions of the concept.

Firstly, we have here been studying situations with multiple lines of (potential) conflict. We have added a centre-periphery axis, to capture the horizontal conflict between engineers and environmental staff,[313] to the original vertical axis of conflict between workers and employers. This enabled us to distinguish between *'integrating'* and *'separating'* company social constitutions, reflecting circumstances where the organisational context enables or hinders cooperation between environmental staff and engineers.

Secondly, the company social constitution has previously been seen as fundamentally a compromise between conflicting interests. This appears to presuppose a situation where neither actor can afford to ignore the interests of the other. In the case of environmental staff, their position is sometimes so weak that other actors – engineers in particular – may well be able to ignore their interests without serious repercussions. We therefore need to re-interpret the concept of the 'company social

[313] White (2006) has also use a centre-periphery model to theorise the role of environmental staff, but not in relation to innovation.

constitution' so as to encompass also those situations where the organisational arrangements and structures governing the relationships between actors are shaped more or less unilaterally.

This adaptation became necessary when studying environmental staff, engineers and management, but we would suggest that it might apply also to the relationship between workers and employers. Previous studies using this concept have taken place in companies with a unionised workforce (as is probably more common in Denmark where most of these studies have been carried out, than in, say, the UK). If one were to study non-unionised workplaces, or workplaces where the labour force was in some other way in a weak bargaining position, the company social constitution may well not be shaped through compromise.

9.2.2.2 'Environmental championing'

We have in this thesis been able to put forth a new theorisation of environmental championing that evades the opposite traps of essentialism and structuralism (as discussed in chapter 3). By linking environmental championing to the career histories and private lives of potential champions as well as to their current situations in the organisation, we have seen that both action and structure components are needed to account for environmental championing.

The main components of the model of environmental championing we propose are:

Career histories	The career choices made, and the career opportunities offered by the organisation.
Hybrid expertise	The bundling of different types of expertise achieved through a career. For environmental championing especially combinations of environmental and technological expertise are relevant.
Interests	An individual's (or group's) interests in promoting his or her career, as well as environmental issues. Interests are here seen

as stemming from the individual's current organisational position, his or her career plans and his or her private life commitments.

Opportunities The opportunities offered by the organisation to an individual (or group) of promoting careers and/or environmental issues. Such opportunities are, in turn, shaped by the priorities and agenda of the company at a specific point in time.

It is worth emphasising the temporal aspect of the model. It takes the history of both the individual (or group) and the organisation into account as important for current events.

We have thus produced a model of environmental championing that does not overly rely on the inherent qualities of a champion, but also emphasises that the organisational, structured context shapes championing. Moreover, this explanation does not make champions heroes in the sense of altruistic do-gooders, but also sees self-interest and career promotion as an intrinsic aspect of an explanation of who becomes involved in environmental championing.

The proposed model also avoids structural determination in two ways. Firstly, we have not reduced the champions to structurally determined products of the organisation, but also highlighted their own interests as a motivating factor. Secondly, this explanation of championing also highlights how the context of the individual – the career opportunities and rewards offered, and the company agenda – are structural aspects of the organisation from the point of view of the individual member of staff making a career and/or promoting environmental issues. At the same time, however, they are action aspects from the point of view of management setting policies on promotions and strategic priorities (assuming that management has, if not a monopoly on, then at least a dominating input in the setting of such policies). Structure and action is in this way co-produced, as is technology and organisation (Russell and Williams 2002:83).

9.2.3 Bringing STS to bear on environmental management literature

We have now presented the most direct theoretical contributions of this thesis. As stated in the introduction chapter, a secondary aim – and a personal 'intellectual project' as it were – has also been to apply Science and Technology Studies (STS) insights to a topic that is usually studied in environmental management research. Here, we shall briefly comment on the progress made in this project.

First, however, we need to avoid defining STS too generously. This thesis has drawn on both STS and a political process perspective. These traditions intersect in, for example, in the work on company social constitutions. Some political process literature, especially Pettigrew (1985), should not be subsumed into STS though. Therefore, it is more correct to claim that we have applied both these schools of thought to the study of environmental aspects of innovation.

Whilst not being the first work in the STS tradition to deal with environmental aspects of innovations (see for example Green *et al*. 1994), this thesis has usefully and in new ways brought lessons from the STS tradition to bear on the study of this area. Firstly, a core insight of STS is that the relationship between intentions behind innovations and technological outcomes is a complex one, and that the 'interpretative flexibility' of technologies means that they are always more or less open to re-interpretation and change (Bijker 1995). Here, we have used this insight to avoid reifying environmental intentions into 'environmental innovations'. By analysing how environmental and other motives were articulated in innovation processes we have been able to reach a more nuanced understanding of environmental aspects of process technology innovations.

Secondly, this thesis has used a political process approach, previously elaborated in STS by for example Clausen (1997), in the study of organisations and environmental aspects of innovation. By analysing the interests and relative power of relevant actors we have contributed to clarifying the relationship between engineers and environmental staff in the context of innovation processes, in a way that would not have been possible using an apolitical approach. Attention to the contributions of multiple actors with varying interests (Burns and Stalker 1961), based on their positions, careers and private life commitments (Morgan 1997:161), has also allowed us to theorise environmental championing in a way that avoids essentialist conceptualisations of champions and encompasses both action and structure.

Moreover, the political process approach (Pettigrew 1985) has helped us avoid the 'environmental management determinist' tendency found in the literature on environmental innovation (that is, a tendency to assume and build explanations that presume continued improvements in environmental management, as discussed in more detail in chapter 2). Having studied the construction, but sometimes also erosion, of organisational structures integrating environmental and technological work, we remain aware of the uncertain future of environmental work in firms and its impact on innovations.

9.2.4 Implications for ecological modernisation and green Marxism

Having discussed the main theoretical implication of this thesis, it is time to look at the wider picture and see what if anything this thesis may contribute to discussions with a society-wide scope. We have in chapter 1 introduced ecological modernisation and green Marxism as rival theorisations of the greening of society. Let us now return to the issues raised there.

As stated in chapter 1, ecological modernisation theory implies that ecological rationality can and will be integrated into existing societal institutions, and that new, more environmentally efficient technology[314] will be an important part of the solution to our environmental problems (Spaargaren and Mol 1992). We have in this thesis seen evidence of such integration in the form of environmental motives, work and expertise being integrated into innovation processes.

[314] The theory especially emphasises the potential of generic technologies like IT, biotechnology and materials technology. Many of the technologies involved in the four cases studied involved IT, especially control systems adopted for automation, quality and resource efficiency purposes.

Nevertheless, it would perhaps be more suitable to talk of 'ecological moderation', since there were clear limits to how environmental motives could be integrated, and to what roles environmental expertise could play in the processes. This result is particularly striking since we have studied countries where environmental concerns are relatively strongly articulated, and one industrial sector in particular - the chemical sector - that has been under fairly strong social pressure to improve its environmental performance for a comparatively long time.

We may also note that the theory appears to predict a rather steady process of improvement, in line with the tendency towards environmental determinism identified in chapter 2. As we have seen there is no reason to assume such automatic progress. Certainly at the company level, environmental-technological organisational structures may erode as well as be built up, depending on the circumstances.

We would suggest that the results of this thesis are more in line with green Marxism. Although there were win-win situations in the companies, there were also plenty of examples of conflicts between environmental and economic motives. The relative primacy of economic motives in the cases and the tendency to subordinate environmental concerns to economic ones, support a view of the irreconcilability of environmental concerns with the 'business as usual' of contemporary capitalist firms. Moreover, the importance of environmental regulation and virtual absence of voluntary environmental action lends further support for green Marxism rather than ecological modernisation theory.

9.3 Contributions to practice

We shall here set out the main practical contributions for policy-making, management and the governance of professional expertise. The section will first discuss implications for environmental policy, and in particular environmental regulation. Secondly, we shall discuss the formation of environmental-technological expertise, and, lastly, present considerations that may be useful for the management of environmental performance in companies.

9.3.1 Innovation and environmental policy

The main lesson for policy from this research is that cleaner innovation is an activity in firms, and not a class of technologies. There is therefore no reason to wait for 'cleaner technology' as a general category to mature, and to hope for greater uptake of it.

At a sectoral level, at a given time, some technologies are more likely to be used for cleaner innovation than others. Pigging technology is an example of this, for at least some process industries, right now. Such technologies will, however, be adopted by firms more often for other reasons than environmental ones. The environmental promises of any technology will thus not necessarily matter to a firm in making the decision to adopt the technology. As a consequence, it is doubtful whether initiatives to stimulate the uptake in firms of particular 'cleaner technologies' (using 'win-win' arguments) will be successful. It is more likely that support for, for example, 'resource efficient technologies' will be more effective.

This is not to say that government should not encourage firms to consider their environmental impact. This is clearly useful, see the discussion about regulation below. Such considerations may also uncover opportunities to improve resource inefficiencies, and in this way lead to cleaner innovation. The point is, rather, that using environmental arguments is likely not to be the most effective way to encourage firms to adopt particular technologies.

In terms of research and development funding, it may still be useful to try to anticipate which new technologies are likely to be used in ways that improve the environmental performance of firm operations, although there will always be uncertainties as to how the technology will be used, and how it will be transformed in use. Most such new technologies will, however, need to offer other advantages to firms to be adopted.

This research confirms that 'command and control' regulation is still important, and that it does have an impact on innovation processes. Regulation mattered in the short term for particular investments, but also in the long term with regard to stimulating integrative company social constitutions, and the formation of potential environmental champions.

This result can be contrasted with the lack of proactivity in the companies studied. It was current and historical regulatory pressure that mattered rather than expectations of future regulation. Moreover, we saw very few examples of voluntary environmental action independent of regulation. Environmental considerations were subordinated to economic ones, unless regulatory requirements were unavoidable.

In terms of policies promoting the adoption of environmental management systems – and insofar as voluntarist accounts put faith in these to drive environmental innovation instead of regulation – we may note that all these companies had such systems,[315] but that it was informal aspects of the organisations, rather than the formal management systems, that channelled environmental concerns (typically rooted in regulatory requirements) into the innovation processes. (See also discussion in next section.) It thus appears much more important to target the informal than the formal organisations, even though that is likely to be more difficult.

We have however seen limited if any impacts of regulation on core process technology. As Clayton *et al*. (1999) suggested, another option may be to provide stronger incentives for resource efficiency and quality, since there are good chances efforts motivated by such concerns will result in cleaner innovation. The relationship between health and safety and environmental performance is more ambiguous.

If it is judged that there is a need for what we have called ambitious cleaner innovation, regulation may have to be reformed to have such effects. This is a matter of giving higher priority to the environmental performance of core technology. The Environmental Impact Assessments and Environmental Technology Reviews required by the regulators in some of the cases are measures that would seem to be suited for this purpose, as they are explicitly about assessing planned investments and technological options. But they need to be made to matter, that is, have an impact on innovation processes, and this might not be easy to achieve.

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[315] In most cases audited ones.

Timing is one aspect of this (as we saw in the Dairy Sweden case, where the Environmental Technology Review happened too late to affect the investment project). A more fundamental problem is that ambitious cleaner innovation is likely to be costly to the companies. As we have seen, cleaner innovation is not necessarily economically advantageous, and ‘ambitious’ here means doing more than what the company could justify by economic concerns. It would seem that economic instruments are therefore well suited to change the balance of what is considered by firms to be acceptable measures. More stringent regulatory targets would be a more indirect way of influencing core technology, and there is a clear risk that the impact would be end-of-pipe innovations rather than cleaner innovation.

Regulators should also be aware of the possibility of ‘empty’ procedural compliance. It is tempting to say: apply pressure or do not regulate, but there are perhaps other advantages of such compliance in terms of preparing the companies for future regulatory requirements. Even if technology is not affected, environmental reporting for example may require measurements to be made and so add to the firm’s knowledge about its environmental impact. We have in this study also not studied non-technological compliance, in terms, for example, of changed operating procedures (although we would expect that also such changes require regulatory pressure).

Finally, regulators may benefit from being aware of the time it may take companies to develop environmental-technological capabilities (compare Hilliard 2001). This research has provided insight into the processes through which company organisations may over time develop routines, networks, etc. that will facilitate integration of environmental concerns into innovation processes, that is integrative company social constitutions. The process of bundling environmental with engineering expertise, that is, of becoming a potential environmental champion, may also be time consuming. We will discuss the formation of expertise more below.

9.3.2 Managing environmental performance through innovation

For a company (or any actor in a company) that wants to gear innovation towards environmental performance, this study may provide some useful insights. We have seen how environmental promotion is both a matter of formal systems and (more importantly) informal networks, both systematic work and contingent championing, both one-off initiatives and well-established routines and practices.

A first point here is not to rely too much on formal management systems. Formal environmental management systems (or even technology management systems) appear to have little impact on innovations.[316] No interviewee ever referred to the environmental management systems in explaining any of the decisions made in the projects. More important are environmental-technological routines integrated with engineering and environmental practice.

Secondly, networks may not be easy to put in place intentionally – just organising environmental staff and engineers together is, as we have seen, not enough for cooperation, for example. Networks will develop when staff have common interests, have a need for cooperation, etc.

Thirdly, rewarding engineers doing environmental work may well help short-term environmental performance. Interestingly it may also help developing skills and careers that will contribute to future environmental-technological capabilities. It may be less easy to promote the development of engineering skills for individuals with an environmental background. Continued recruitment of engineers into environmental staff positions will be necessary, at least until there is a supply of people with environmental degrees with a substantial engineering component.

Finally, it is important to be aware that it may take time to develop environmental-technological capabilities, in the form of: established routines, informal networks and staff with hybrid skills – substantially longer time than it takes to propose a new

[316] Hilliard (2001:18) supports this result for Irish pharmaceutical companies. Richards *et al*. (2004:392, citing an article about the Environment Agency in ENDS Report) claim that environmental management systems do not even reliably indicate regulatory compliance.

initiative, assemble a project team or hire a consultant. But once in place, such capabilities may be very effective.

9.3.3 The formation of environmental-technological expertise

This study also has interesting implications for anyone who has an interest in how technological and environmental professional expertise is formed (that is, not just the state, but also professionals, professional bodies, etc.). There may be ways to strengthen the kinds of hybrid environmental-technological expertise studied here, through changed structures of occupational formation.

With regard to higher education, and in both countries, this research supports the provision of environmental education for engineers. Also, and not least, it is important to provide environmental professionals with engineering skills, if they are to have good prospects for working in industry. It may be a good idea to review the relevant educational programmes for environmental degrees, to see how much technological content there is, and if needed augment this. To the degree that, in the UK more than in Sweden, individuals trained in science do engineering work, these considerations apply also to science education.

In the UK there is, as previously mentioned, an institute for environmental engineers, as well as a few other institutes for environmental professionals of different types (waste managers, environmental managers, etc.). It seems, however, that none of these institutes specifically targets manufacturing industry. Furthermore, and more importantly, they tend, insofar as they deal with technology at all, to be more focussed on end-of-pipe than core technology. There may be scope for an institute in the UK for ‘industrial environmental engineers’ that requires of their members skills relating to, among other things, core technology. The scope for this in Sweden is smaller, given the different structures there for occupational formation.

9.4 The impact of the chosen methodology

In this section, we shall discuss the main advantages and disadvantages of the methodological choices made, and their impact on the results of the study. The choices discussed pertain to case studies and the comparative dimension of the analysis.

A choice was made to use case studies (based on interviews) rather than a survey. A survey would have provided data from which statistical generalisations could have been made. A survey would, however, have been less useful in capturing the contingencies of particular instances of innovation and would inevitably have generated a less rich understanding of the situated complexities of organisational dynamics.

A central choice made was that to undertake multiple case studies, which has proven very useful. (Further points are made below on comparison between cases.) There was, however, a trade-off to be made between a longitudinal study and multiple case studies. To some extent the cases have a longitudinal dimension, based on asking the interviewees about their and the companies' history. But the time spent collecting data from each case was limited, and recall has its limitations in terms of, for example, accuracy and *post hoc* rationalisation. A deeper understanding of the political processes would perhaps have been possible using a 'true' longitudinal approach (Pettigrew 1985), but this would have come – within the constraints of this research project – at the price of the analytical leverage gained from multiple case studies.

A core strength of this thesis is the selection of other than just 'best practice' ones. The cases provide a range of levels of environmental ambition, and of environmental outcomes. This has allowed us to avoid environmental determinism, and no assumptions have been made that these cases represent future practice. Nor is the focus just on environmental practices in the companies. Instead we have tried to situate the design choices made in the broader context of both engineering and environmental practices and agendas, as well as the broad range of motives behind them. By avoiding using a 'green lens' that is studying only 'best practice' environmental improvements, we have been able to see the impact, or the lack of an impact, of different environmental practices in context, further undermining common but weakly supported assumptions about the future usefulness of such practices.

A final point relating to the case studies is the choice to focus on core technology. The cases did include end-of-pipe technology innovations, but they have received somewhat less attention here, when they were organised in separate projects. The core technology focus ensured that we have studied projects that were economically important to the companies, and so helped us in studying how environmental motives fit or not with core company concerns. It also allowed a detailed analysis of cleaner technology, forming the basis of a central theoretical contribution of this thesis.

We chose in this project to compare cases in two industries and in two countries. This choice clearly paid off in terms of the clear sectoral differences we observed, not least in terms of the role of regulation, but also at the organisational level. The country dimension, however, gave us surprisingly little analytical leverage. It was expected to matter in several ways. Firstly, it mattered in terms of differences in regulatory structures. It would appear though that for core technology innovation (at least in these middle to large size companies), that what matters is the regulatory pressure applied, rather than formal differences in regulation (having one or several permits per site for example).

To illustrate this we may compare the two dairy cases. The Swedish dairy company had an environmental permit, but not the Scottish one. The presence of a permit gave the local Environmental Coordinator at the Dairy Sweden site a role in the project, but little or no influence in the absence of strong regulatory pressure. The difference in the organisation of regulation was similarly superficial. In Scotland there is a central body (Scottish Water) and in Sweden a decentralised and fragmented system of local municipalities monitoring environmental performance. The member of staff at Scottish Water however had a local remit, and there was little obvious difference in the levels of expertise between him and the Swedish municipality staff member. Furthermore, Scottish Water has a dual role of being both regulator and effluent treatment service provider, but in the Swedish case the municipality also runs the municipality effluent treatment plant. The end result was that similar compromises and judgements were made in the two cases.

Finally, we expected the generally somewhat higher levels of pro-environment attitudes in Sweden to make some difference. This does seem to have made a difference in terms of the motivations for environmental championing. All in all, we expected a stronger impact of national differences, but can conclude that the sectoral context and history were more important.

9.5 Further research

We shall here set out some ideas for further research: firstly, by following up on one of the points made in the previous section; thereafter by discussing alternative settings and contexts to the one chosen for this project; and, lastly, by developing a political theme (as in striving towards societal-level change as opposed to organisational politics, although these two meanings of 'politics' may interrelate) touched upon in this thesis.

As mentioned in the previous section, it might be worthwhile to add a more developed longitudinal component to this research. Further understanding of especially the political aspects of the organisational determinants of the integration of environmental concerns into technological change in companies, could be gained from returning to the case companies studied here in future projects.

To gain further insights into the integration of environmental rationality in technological change, there are also other settings and contexts than technology adoption in process industries that deserve attention. A first area is up-stream activities in the innovation processes, for example company technology development activities or academic research.

This issue of self-regulation could be explored by studying emerging technologies, which have yet to be adopted in routine use in companies. Marine energy technologies, for example, are interesting in this respect. Any future implemented generating capacity would undoubtedly be subject to environmental regulation, and even though the shape of this future regulation is uncertain, developers and researchers may still have to take it into account in their work. This would perhaps provide a contrasting setting where we should see more environmental pro-activity than was the case in the manufacturing companies studied here.

In academia, environmental subjects and research areas have grown considerably over the last 30-40 years. It would be of interest to deepen our understanding of how environmental concerns have been integrated into engineering faculties in this period (see Jamison 2001 for a more general discussion of the uptake of environmental ideas in academia). Have environmental concerns had to be re-shaped to fit in with dominant frames of reference in academic engineering? Has the integration of environmental concerns had an impact on engineering research results? How have such concerns been received by researchers in other areas, which are perhaps less easily labelled political or activist?

A second interesting area would be the integration of environmental concerns into technology (science, research, innovation) policy. Were environmental concerns perhaps more prominent before technology policy was transformed into innovation policy, with its somewhat stronger focus on economic growth, during the last 25 or so years? If so, how could this policy shift happen simultaneously with the breakthrough in many countries of green parties? Is there a renewed interest in environmental – and other 'societal' concerns apart from economic growth – in innovation policy, as seems to be the case when looking at the most recent EU R&D framework programmes?

Apart from these different settings, there is also a political strand in the thesis that could be further developed in several ways. An area that could offer interesting comparisons to this research would be cases of technology-oriented cooperation between companies and environmental NGOs. In the cases studied the main external leverage for environmental staff and environmental champions was regulation. What would the effects on company organisational dynamics be from adding NGO activists and experts to the brew? Contrasting the company and NGO settings might also shed light on the role of different environmental ideologies in organisations. The topic of company-NGO collaboration would give an opportunity to bridge the divide between organisational research and research on political (‘social’) movements. Pettigrew drew on social movement literature (1985:478) developing his political process approach to research on organisations, but the two areas of research appear still to be largely separate bodies of work.

A related aspect of the research undertaken that could be further analysed and developed is the private and professional identities of the people involved, and how they negotiate any private life environmental commitments in work places in industry. There appears to be a more or less common business culture of ‘environmental pragmatism’ (even in companies with a high environmental profile, see Crane 2000) in the companies studied, and there are, as indicated peripherally in this study, different ways of negotiating the fit or tension between private and professional identities.

The logical conclusion of this topic of ‘environmental identities’ is perhaps to start with political activism rather than organisational life, and study what environmental activists do at work. Do they express their activism in the workplace, that is, outside the environmental movements they are involved with? And how do their environmental identities develop if they cease to be active in environmental movement organisations? The literature on social movements appears to have little (apart from a few exceptions like Meyerson and Scully 1995 and McAdam 1989) to say about life and identities outside and after involvement in movement organisations.

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Appendix A Interviewees

The tables give the interviewees' position in the company at the time of the projects.

Table A.1 Interviewees Chemicals Sweden

Position	Main role in project	Date
Consultant	Project leader	11/06/03
Process Engineer, Service Unit Sweden	Managed process engineering group	11/06/03; 26/01/04 (tel.)
Operator, plant	Took part in consultations	18/06/03
Maintenance Manager, plant	Expert on maintenance and other issues, organised worker consultation	25/06/03
Environmental Coordinator, plant	Linking project with other environmental activities	24/06/03
Plant Manager	Led pre-study, acted as internal customer	05/09/03
Environmental Engineer, HSE	Linking project and HSE department	25/06/03
Safety Engineer, HSE	Risk analyses	24/06/03
Manager, HSE	Expert on environmental issues	13/06/03 (tel.)
Shop Steward	*	03/09/03
Official, County environmental division	*	05/09/03
Manager, Municipality environmental division	*	18/06/03
Manager, product stewardship	*	18/06/03
Researcher/Sales	*	11/06/03

Note: '*' these interviewees were not involved in the project, but have provided background information.

Table A.2 Interviewees Chemicals Scotland

Position	**Main role in project**	**Date**
Process Engineer	Project leader	6/3/03; 9/5/03 (tel.)
Work Station Manager	Represented manufacturing	17/4/03
Site Environmental Advisor	Managed relations with regulator	17/4/03
Corporate Safety Advisor	Led hazards studies	19/5/03
Corporate Advisor on Environmental Technology	#	11/10/02
Shop Steward	*	28/04/03
Technical, Development and Environmental Manager	*	22/8/02; 24/2/03 (tel.)
Process Engineer	*	12/2/03

Notes:

1) '*' denotes interviewees who were not involved in the project, but who has provided useful background information.

2) '#' Was involved in project, but I have not talked to him about it, since I had not chosen the project at the time of the interview.

Table A.3 Interviewees Dairy Sweden

Position	Main role in project	Date
Technology Director (D)	Internal customer	23/06/04
Environmental Specialist (D)	Permits	03/06/04 (tel.)
Project Manager (D)	From re-localisation investigation to implementation	09/06/05
Technology Manager (P)	Coordination of project and on-going production	17/05/04
Environmental Coordinator (P)	Environmental controlling	19/05/04 (tel.)
Engineer (P)	Project engineer	08/06/04
Communication Officer & Chairman of white-collar union (P)	Internal information dissemination, representing union	28/06/05 (tel.)
Operator & Chairman of blue-collar union (P)	Representing union	28/06/05 (tel.)
Consultant Engineer, Plant Tech	Main project leader	13/05/04
Consultant Engineer, Dairy Tech	Design, led part of project	07/06/04 (tel.)
Environmental Consultant	Reviewed cleaner technology options	24/06/04
Environmental Officer, Council	*	07/06/04
Current Environmental Coordinator (P)	*	17/05/04

Notes:
1) '*' these interviewees were not involved in the project, but have provided background information.
2) (D) – Division, (P) – Plant

Table A.4 Interviewees Dairy Scotland

Position	Main role in project	Date
Technical Director	Project manager	03/12/04
Group Environmental Manager	*	20/12/04
Senior Project Manager (S)	Project manager	11/03/05
Senior Project Engineer (S)	Managed mechanical side	11/03/05
Senior Project Manager (S)	Managed control system side	11/03/05
Software Engineer (S)	Designed the management information system	11/03/05
Software Engineer (S)	Worked on the design of the control system	11/03/05
Scottish Water, Trade Effluent Advisor	*	04/04/05

Notes:
1) '*' these interviewees were not directly involved in the project, but have provided relevant information.
2) (S) – Supplier